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**Dingman et al.**

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(54) **SUBSEA SEDIMENT SEPARATION AND FILTRATION SYSTEM**

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(73) Assignee: **DELTA SUBSEA LLC**, Montgomery, TX (US)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **18/096,226**

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(65) **Prior Publication Data**

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**Related U.S. Application Data**

(62) Division of application No. 17/395,265, filed on Aug. 5, 2021, now Pat. No. 11,649,176.  
(Continued)

(51) **Int. Cl.**  
**C02F 1/38** (2023.01)  
**B01D 21/26** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **C02F 1/38** (2013.01); **B01D 17/0217** (2013.01); **B01D 21/267** (2013.01); **B09C 1/00** (2013.01);  
(Continued)

(58) **Field of Classification Search**

CPC ..... C02F 1/38; C02F 1/40; C02F 2101/32; C02F 2103/08; C02F 2103/10;

(Continued)

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*Primary Examiner* — Liam Royce

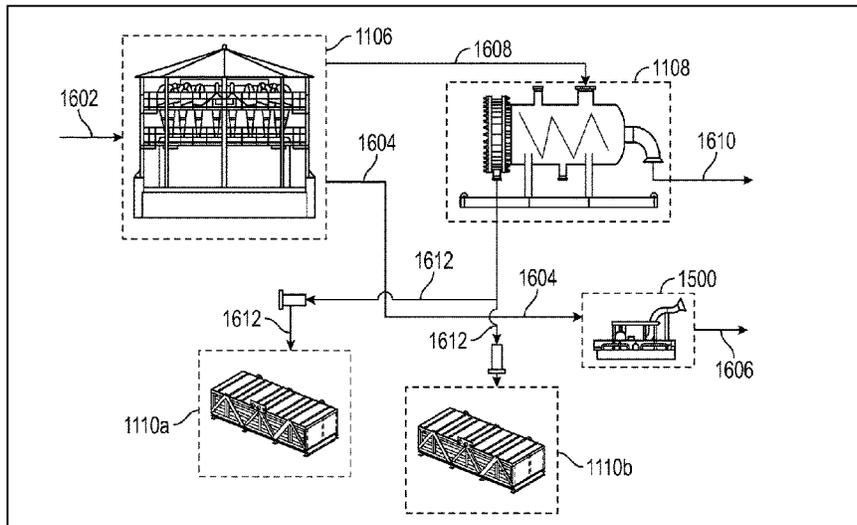
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(57) **ABSTRACT**

A disclosed subsea sediment separation and filtration system includes first and second separation devices, a spreader apparatus, and a storage device. The first separation device receives a water/sediment/oil mixture and from a subsea surface and separates the mixture into a first component containing cleaned sediment and a second component containing a water/oil mixture. The spreader apparatus disperses the cleaned sediment of the first component into a subsea environment of the spreader apparatus. The second separation device receives the second component from the first separation device and separates the second component into a cleaned water component and an oil component. The second separation device disperses the cleaned water component into a subsea environment of the second separation device and provides the oil component to the storage device. The first separation device may include a plurality of hydrocyclone devices, and the second separation device may include a high pressure hydrocyclone device.

**8 Claims, 33 Drawing Sheets**

1600 →



**Related U.S. Application Data**

(60) Provisional application No. 63/062,410, filed on Aug. 6, 2020, provisional application No. 63/061,288, filed on Aug. 5, 2020.

(51) **Int. Cl.**

**B01D 17/02** (2006.01)  
**C02F 1/40** (2023.01)  
**B09C 1/00** (2006.01)  
**E02D 19/04** (2006.01)  
*C02F 101/32* (2006.01)  
*C02F 103/08* (2006.01)  
*C02F 103/10* (2006.01)

(52) **U.S. Cl.**

CPC ..... **C02F 1/40** (2013.01); **C02F 2101/32** (2013.01); **C02F 2103/08** (2013.01); **C02F 2103/10** (2013.01); **C02F 2301/066** (2013.01); **C02F 2301/08** (2013.01); **E02D 19/04** (2013.01)

(58) **Field of Classification Search**

CPC ..... C02F 2301/066; C02F 2301/08; B01D 17/0217; B01D 21/267; B09C 1/00; E02D 19/04  
See application file for complete search history.

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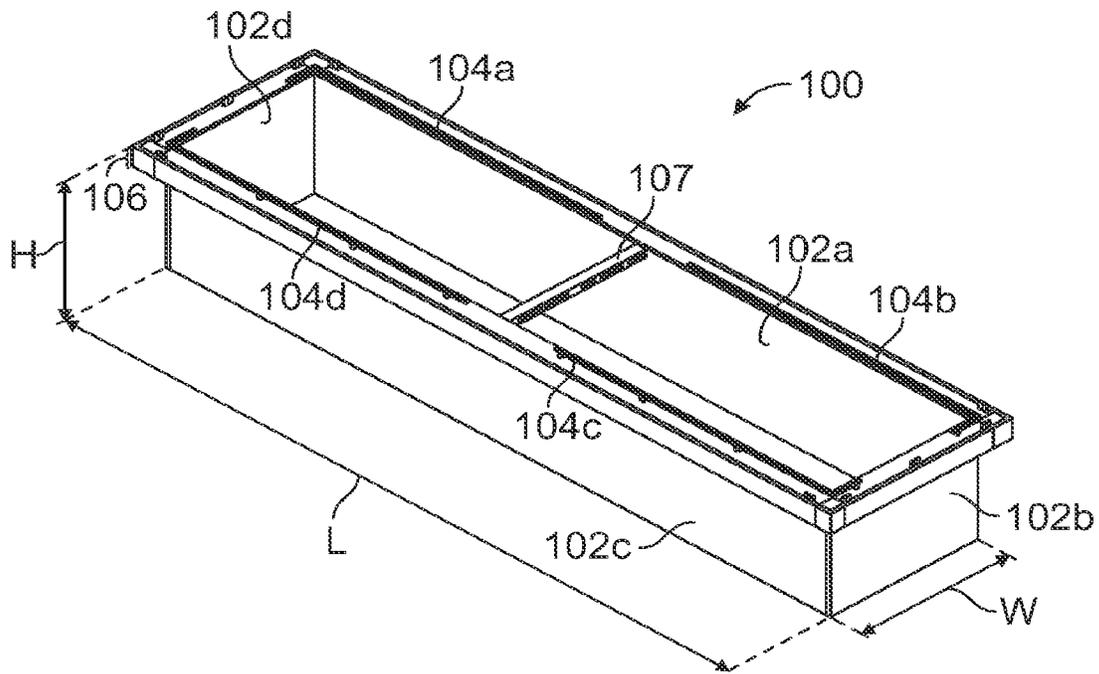


FIG. 1

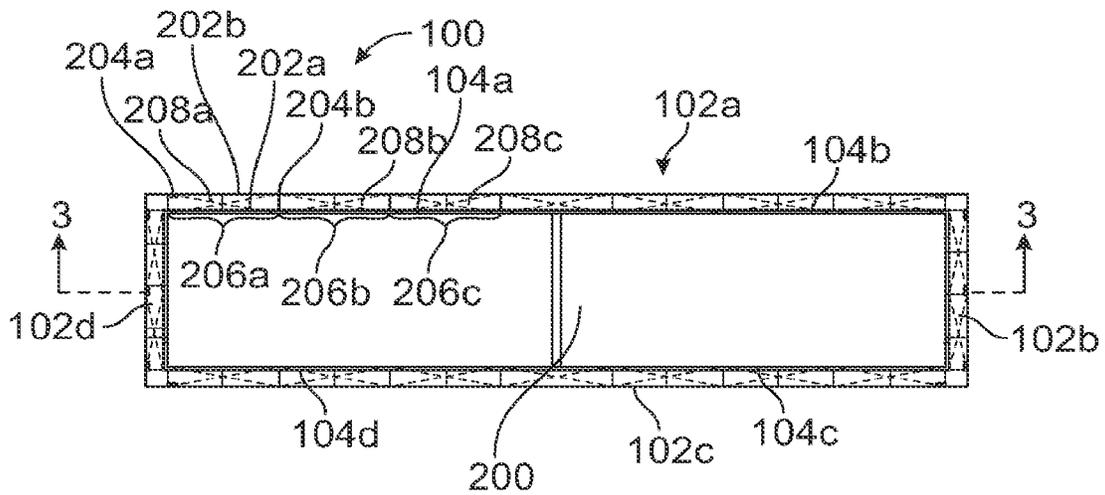


FIG. 2

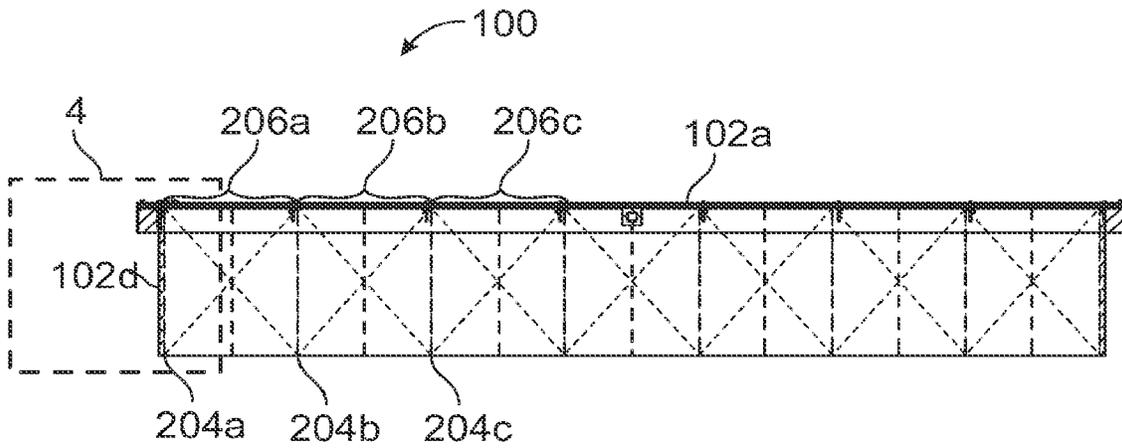


FIG. 3

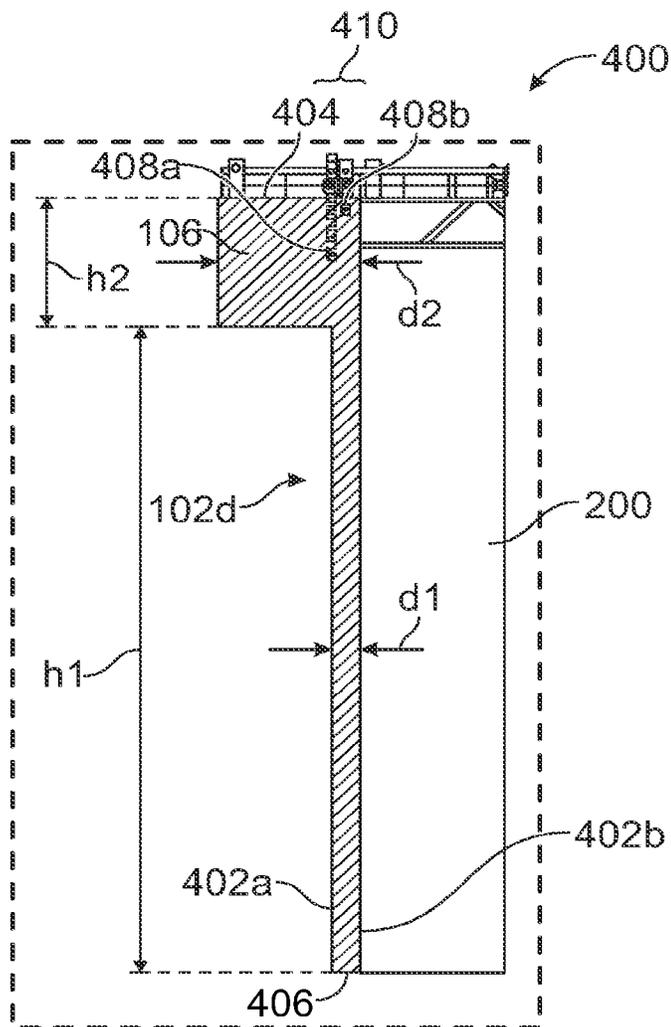


FIG. 4

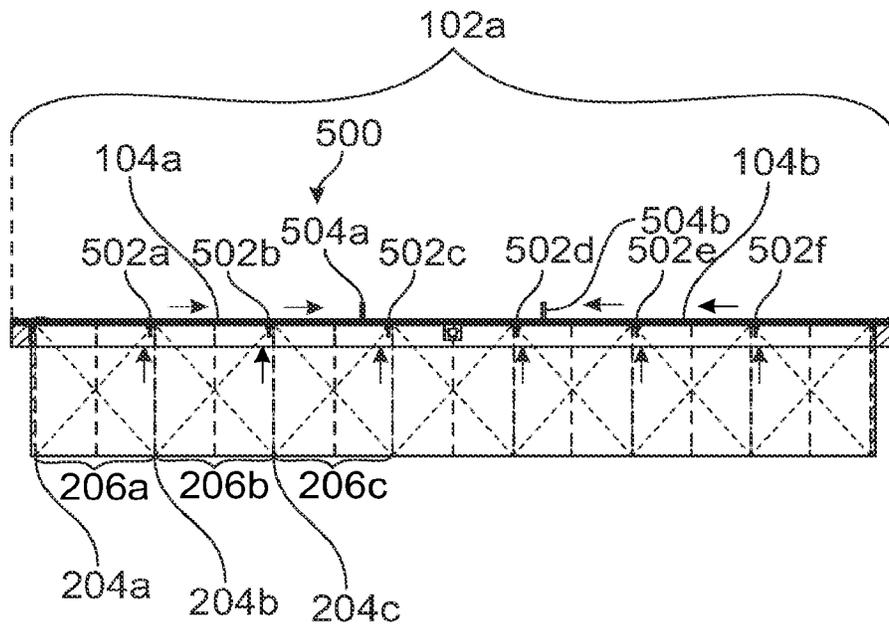


FIG. 5

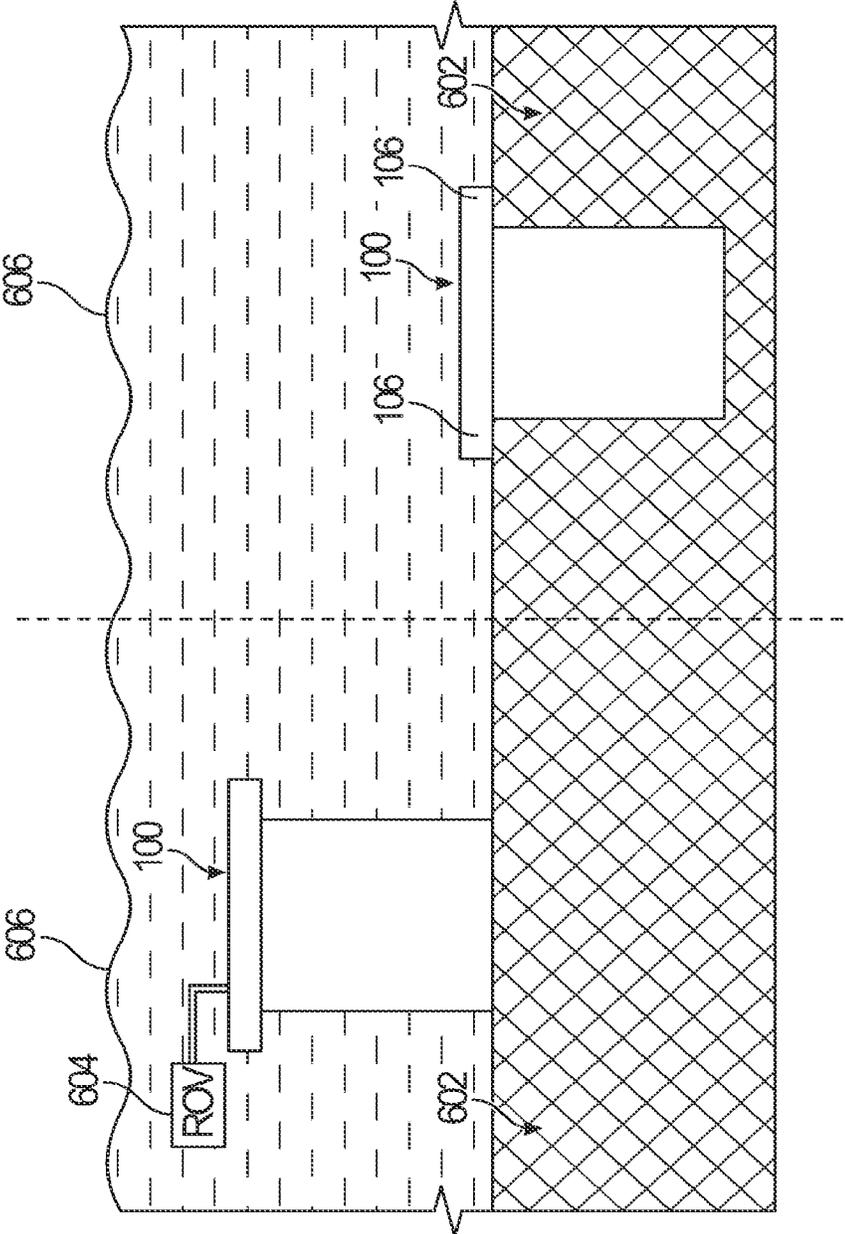


FIG. 6A

FIG. 6B

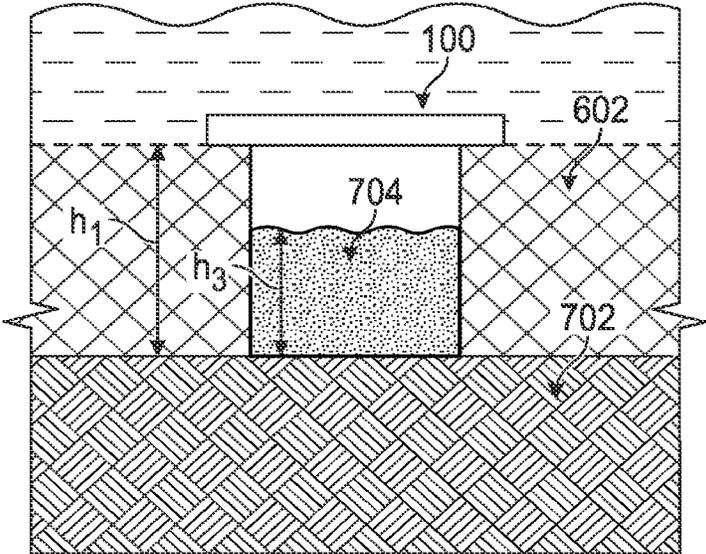


FIG. 7

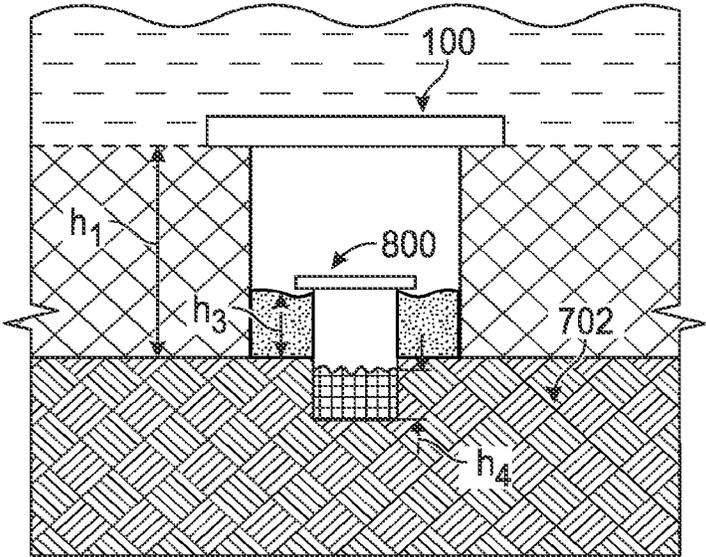


FIG. 8

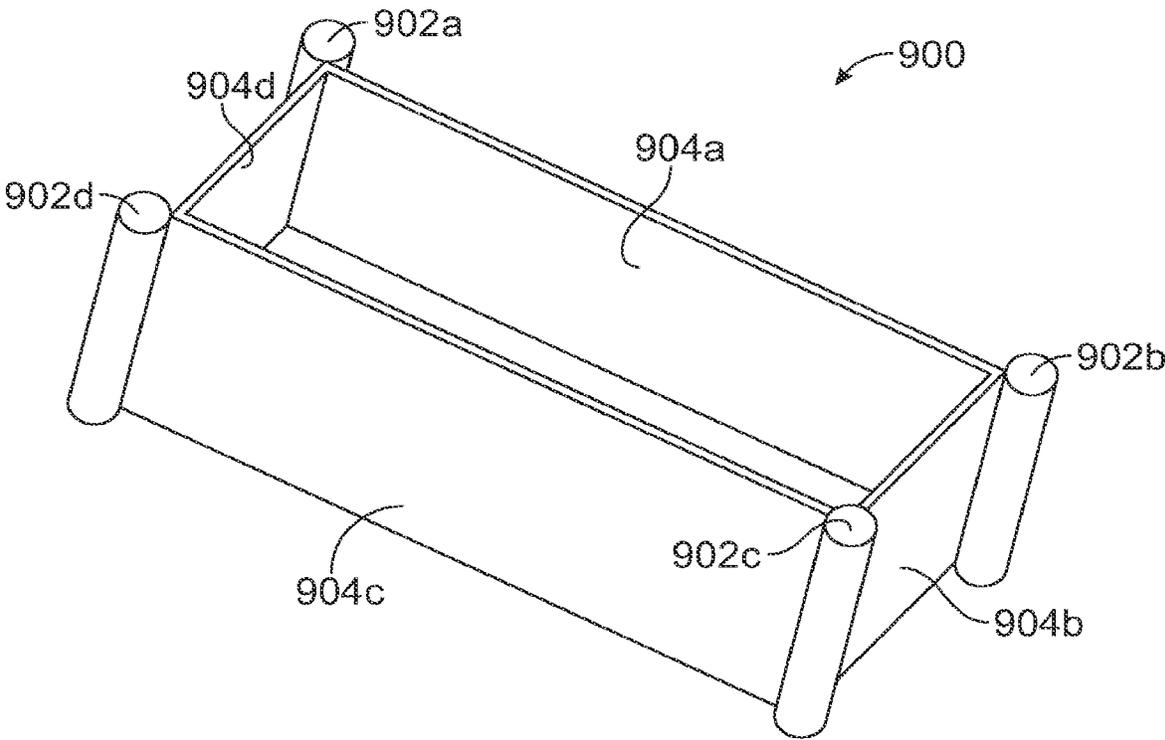


FIG. 9

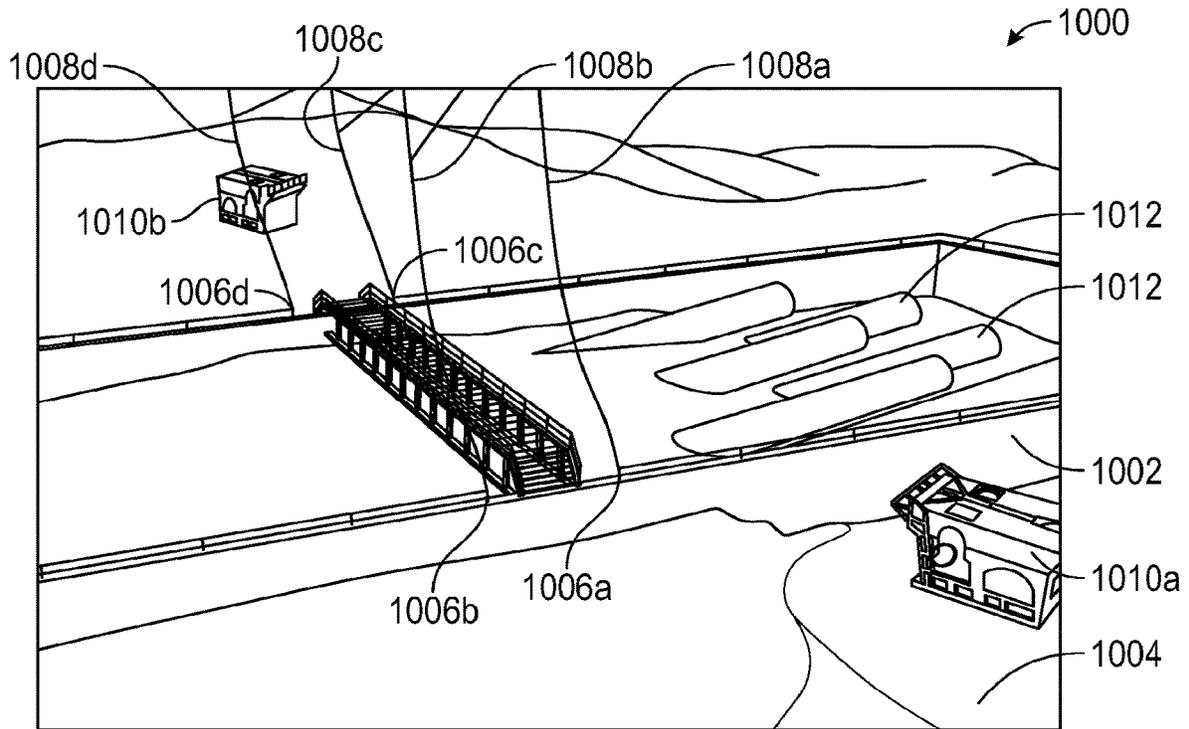


FIG. 10

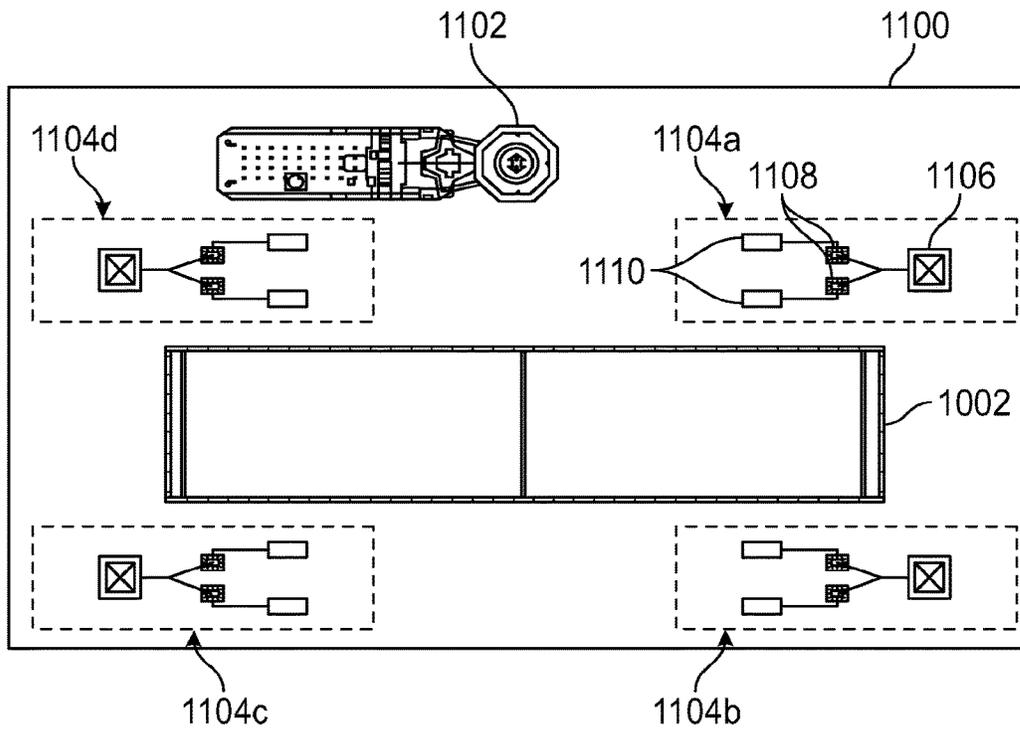


FIG. 11A

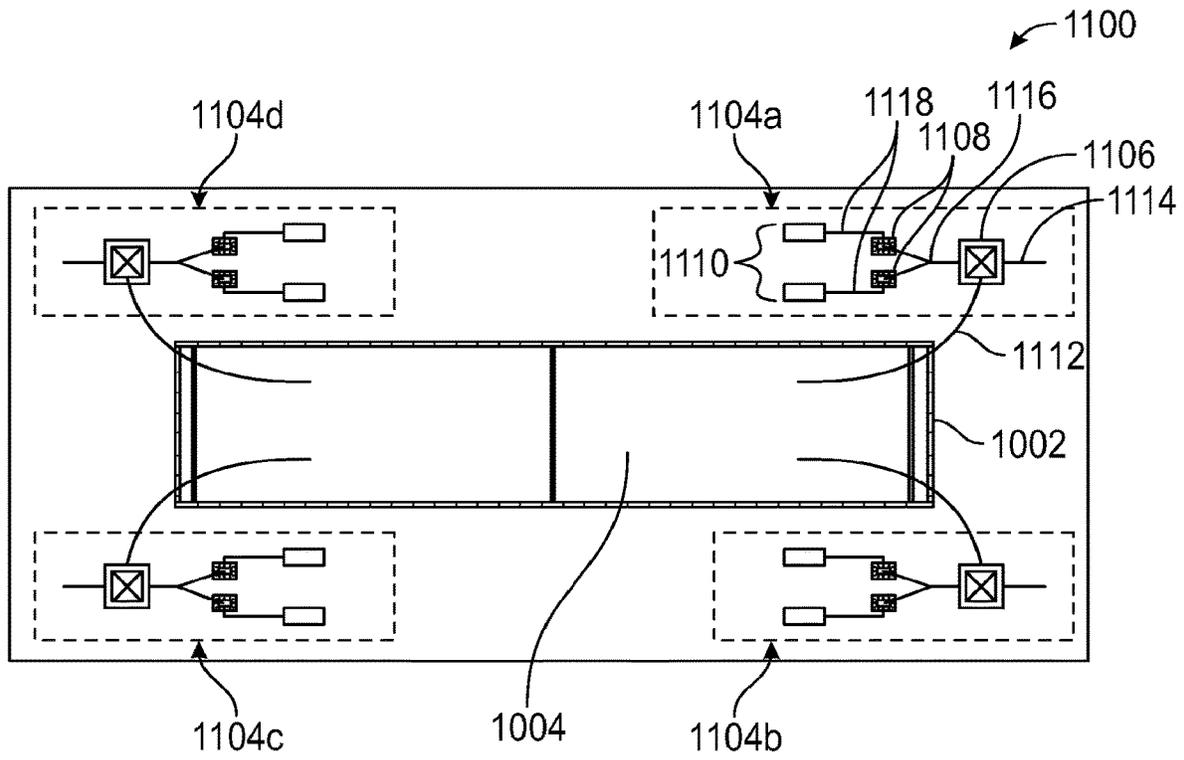


FIG. 11B

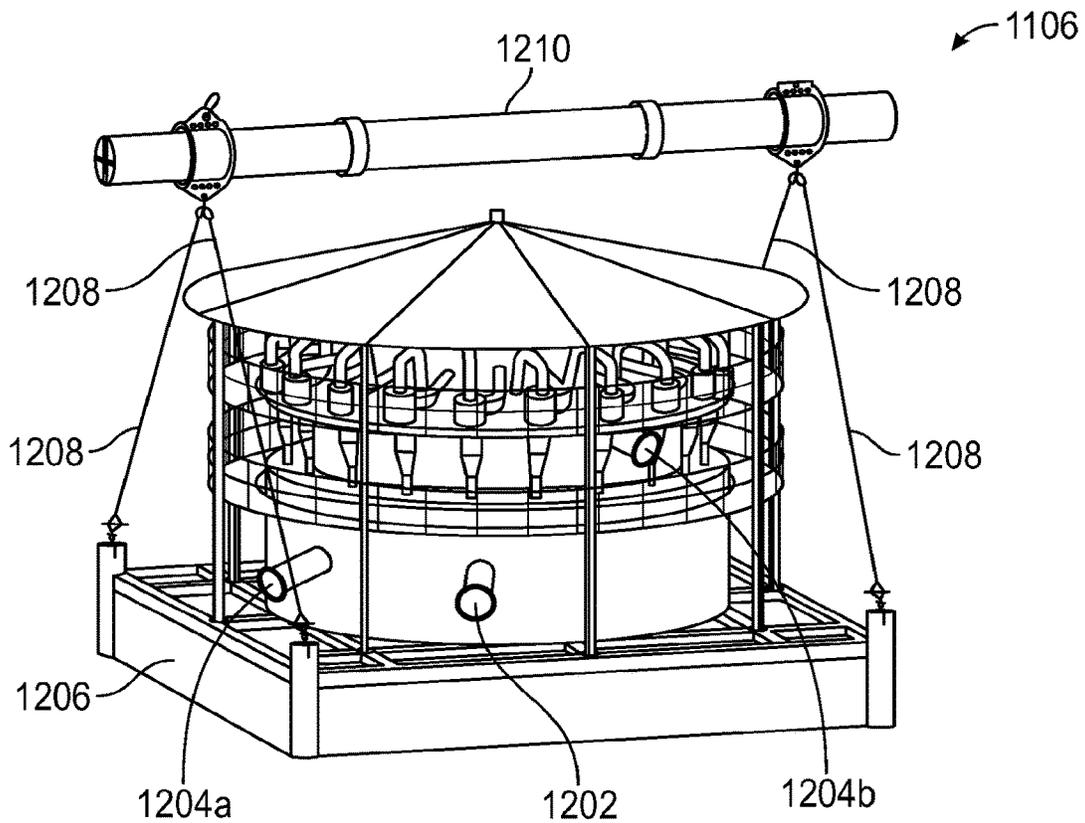


FIG. 12A

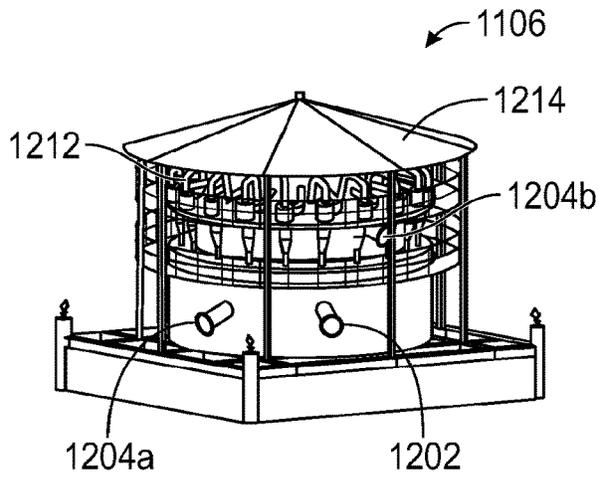


FIG. 12B

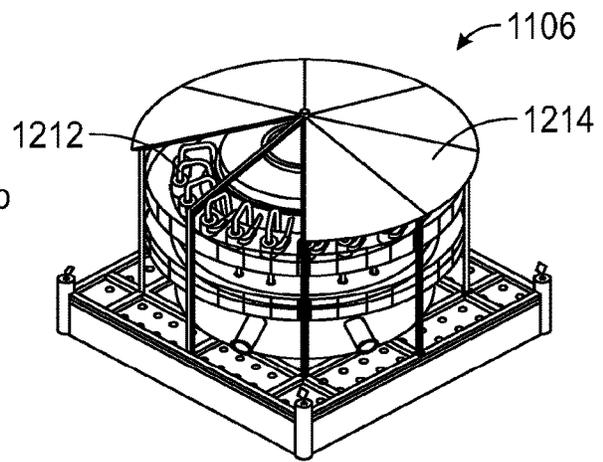


FIG. 12C

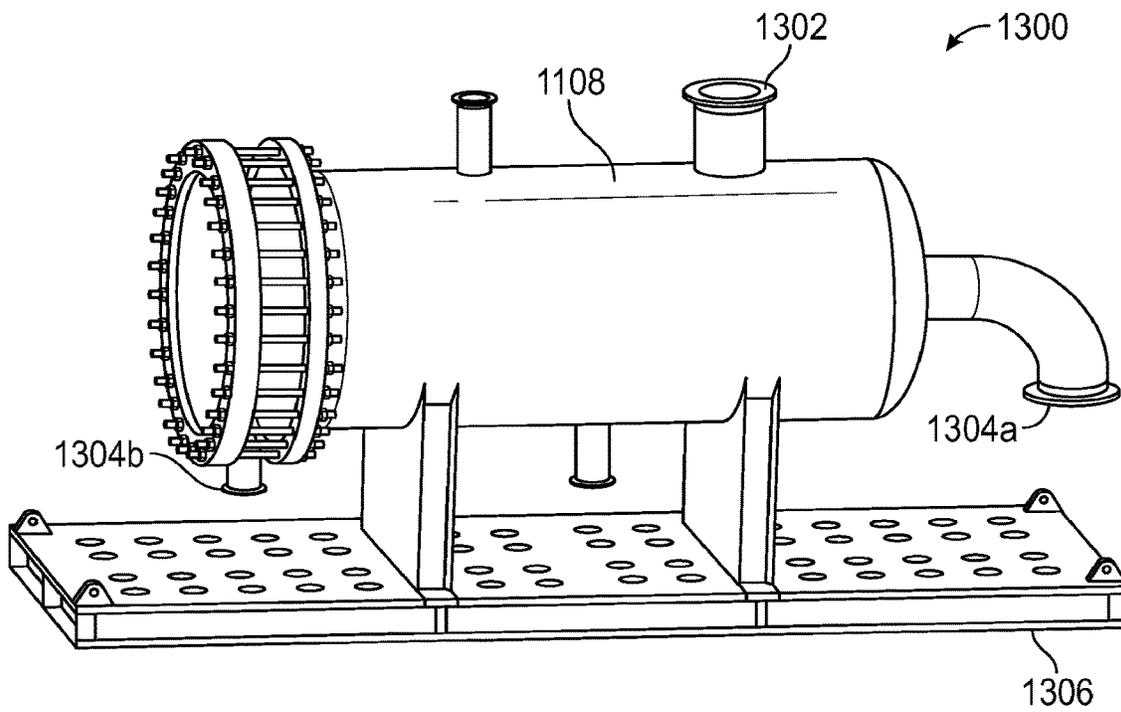


FIG. 13

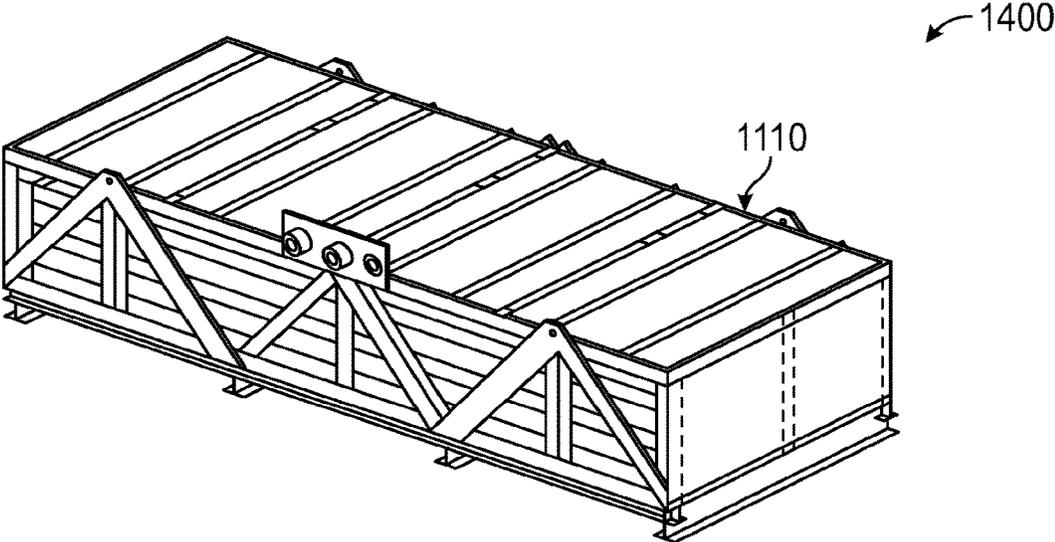


FIG. 14

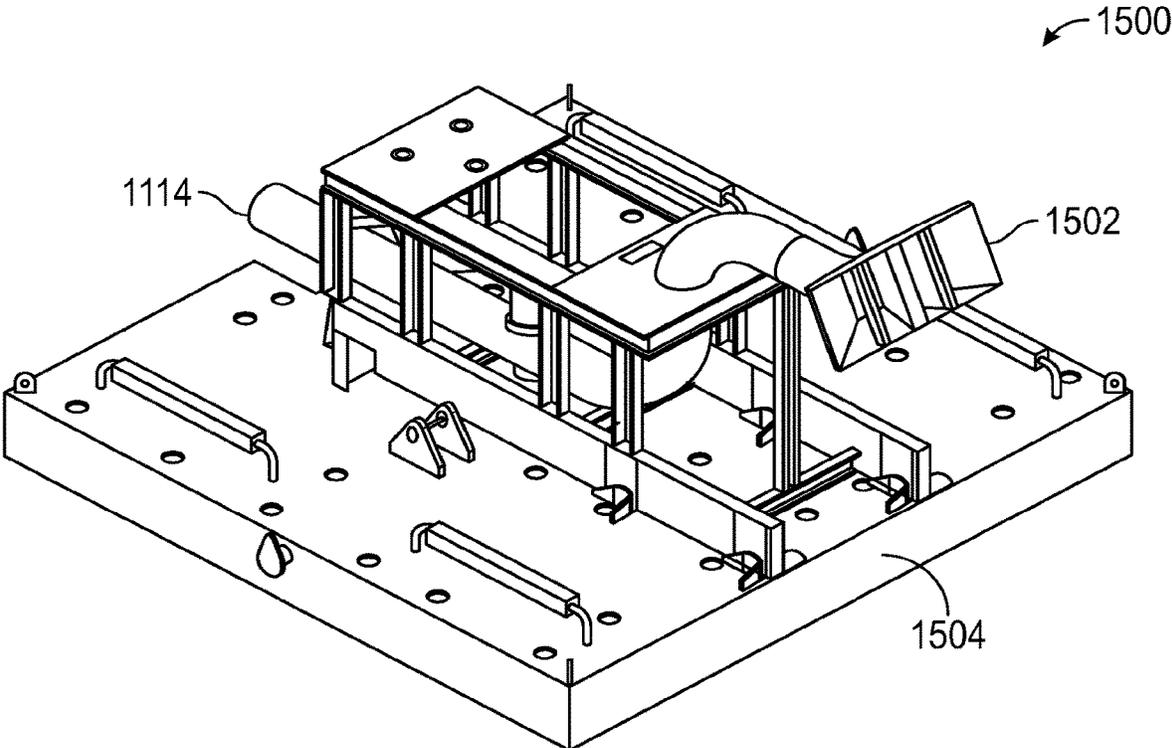


FIG. 15

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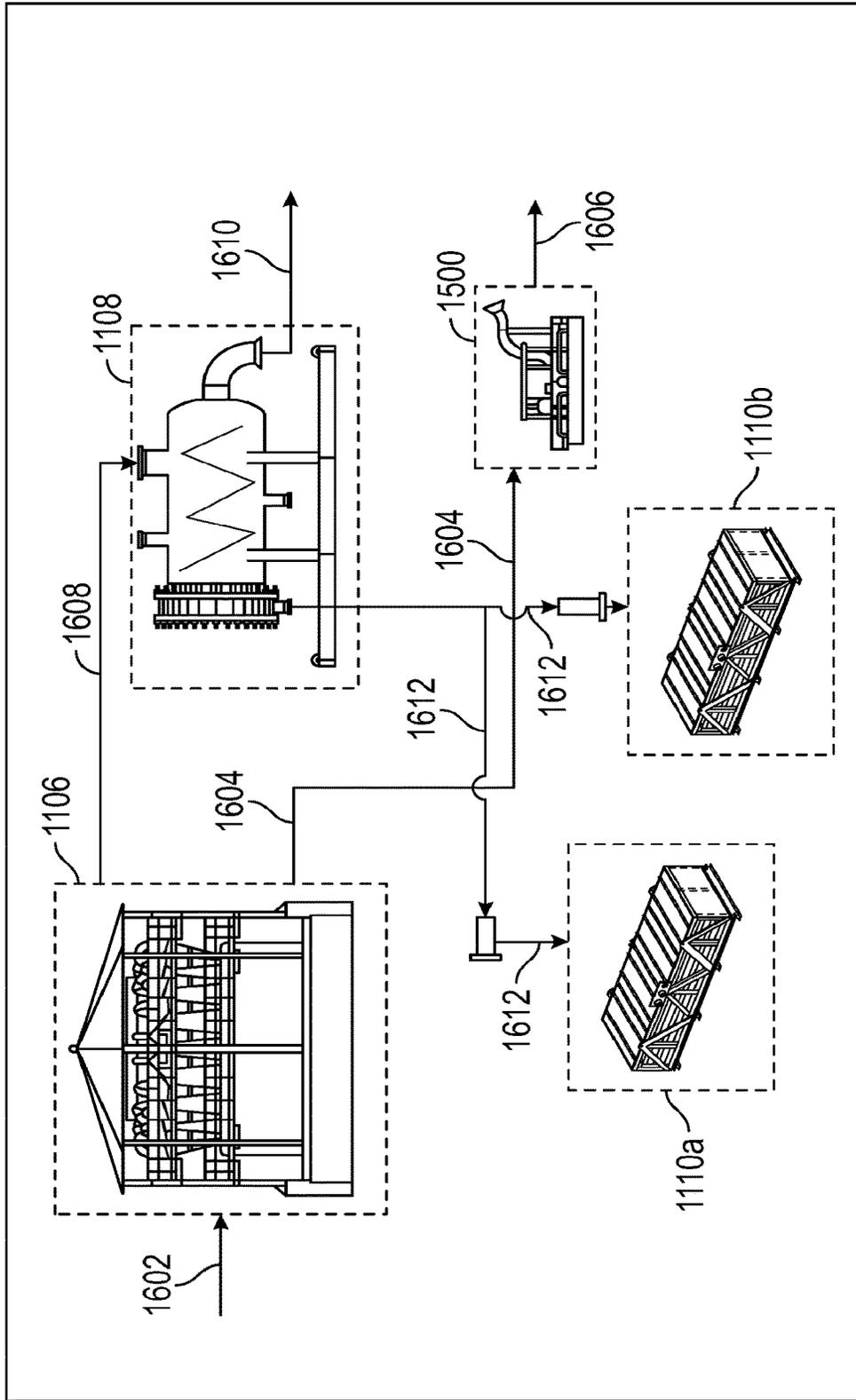


FIG. 16

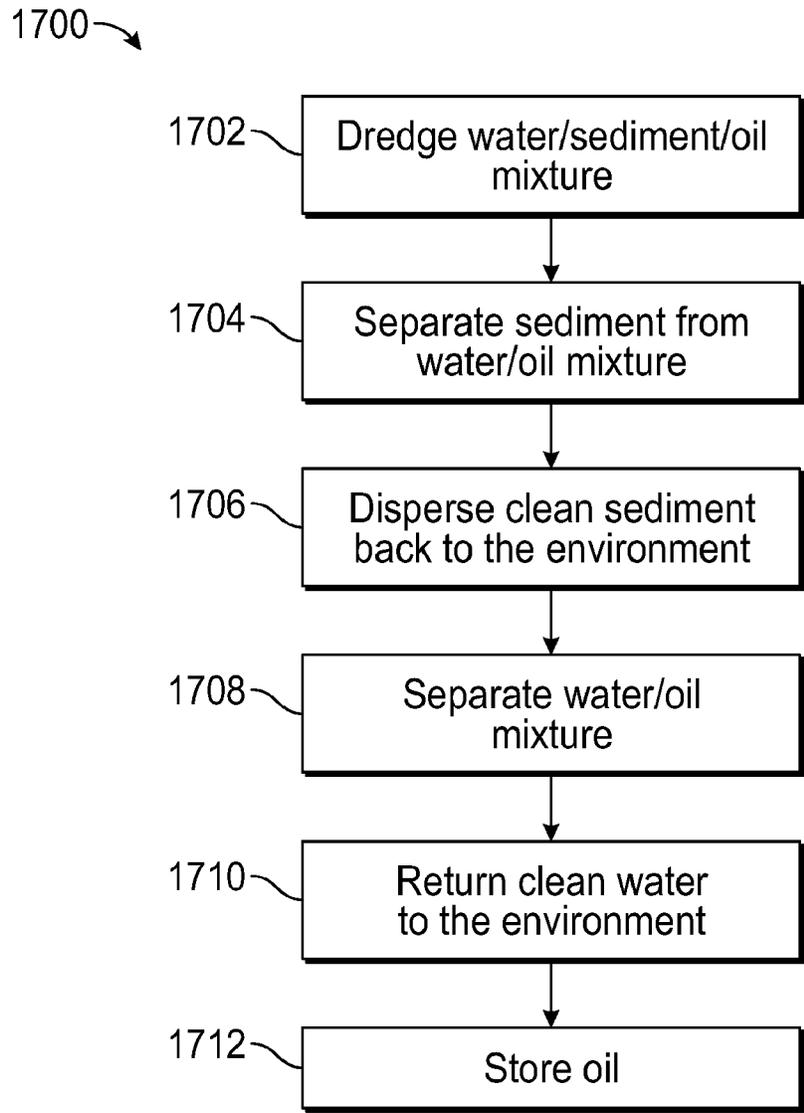


FIG. 17

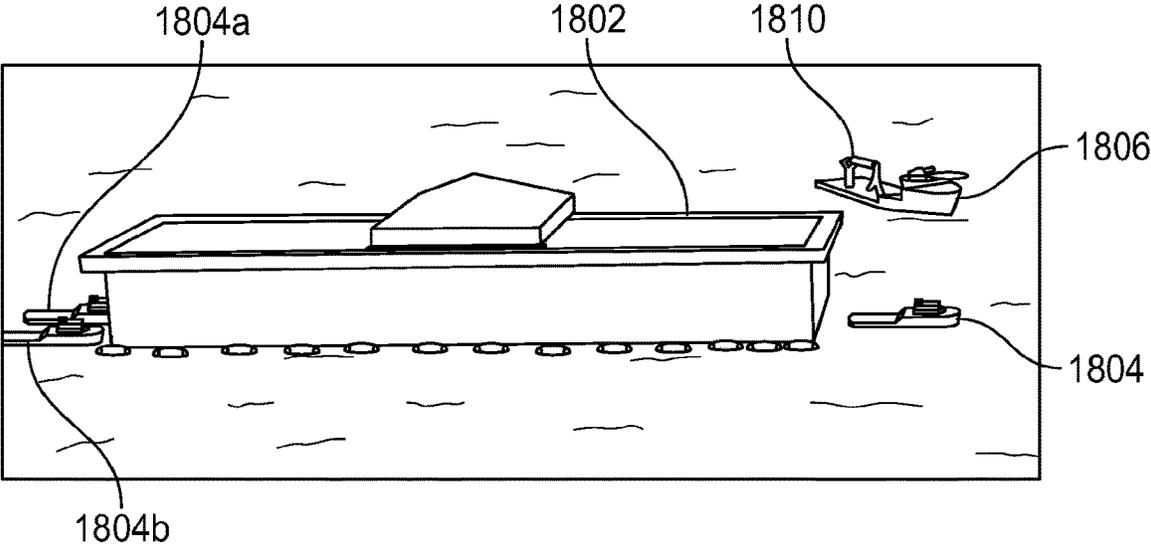


FIG. 18

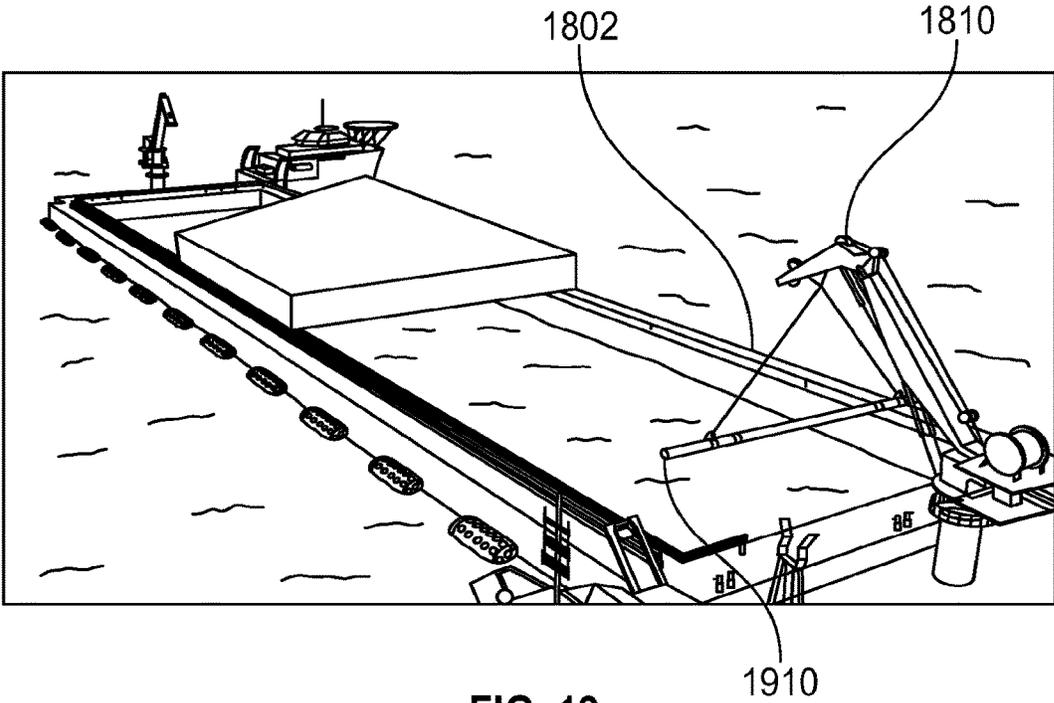


FIG. 19

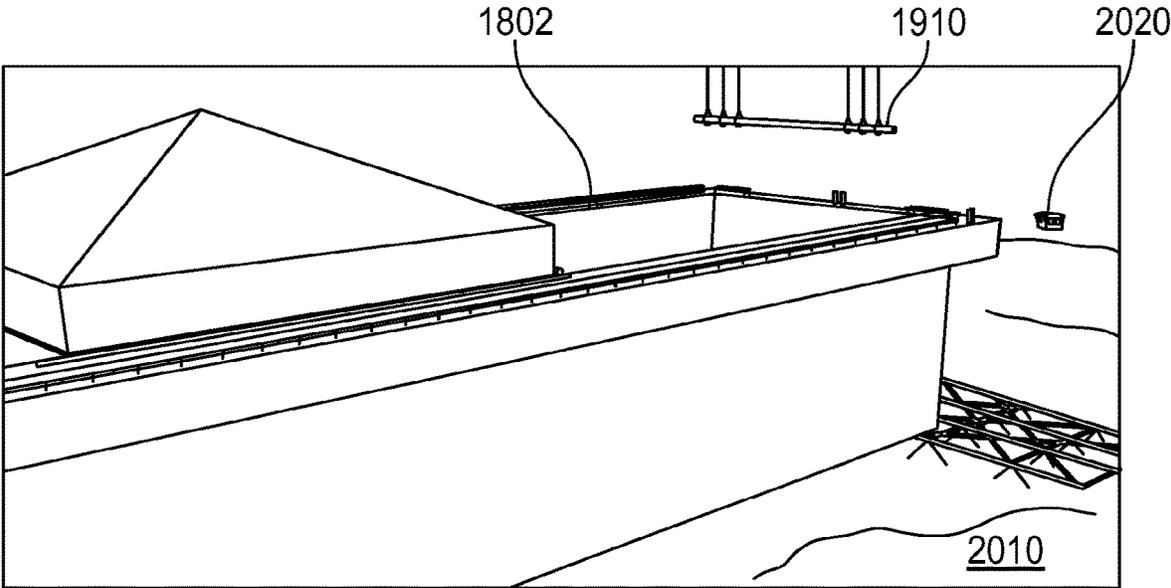


FIG. 20

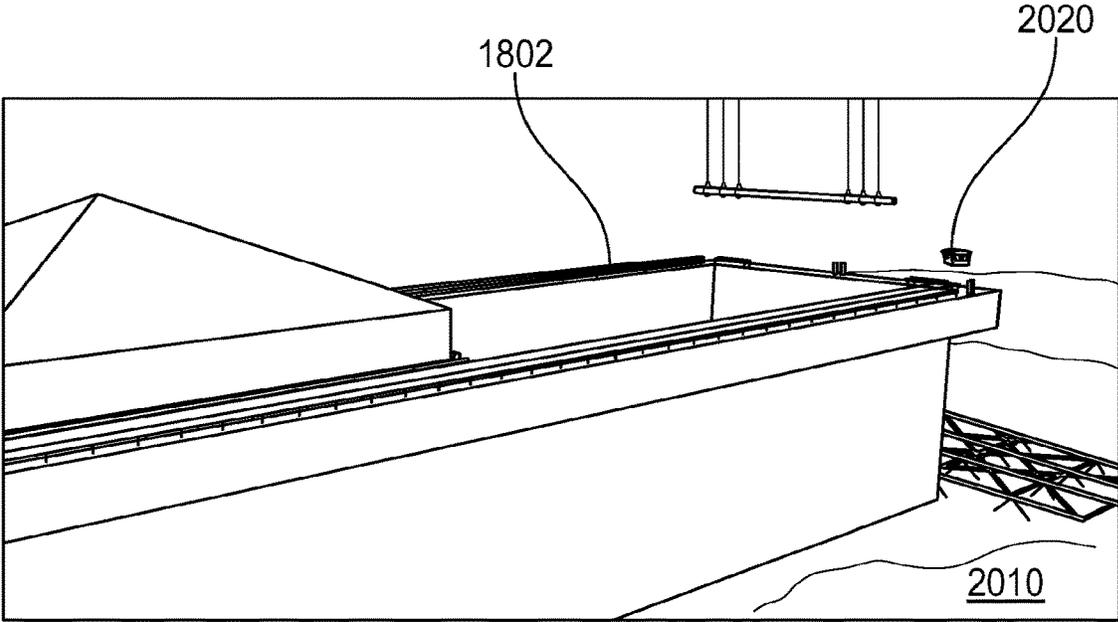


FIG. 21

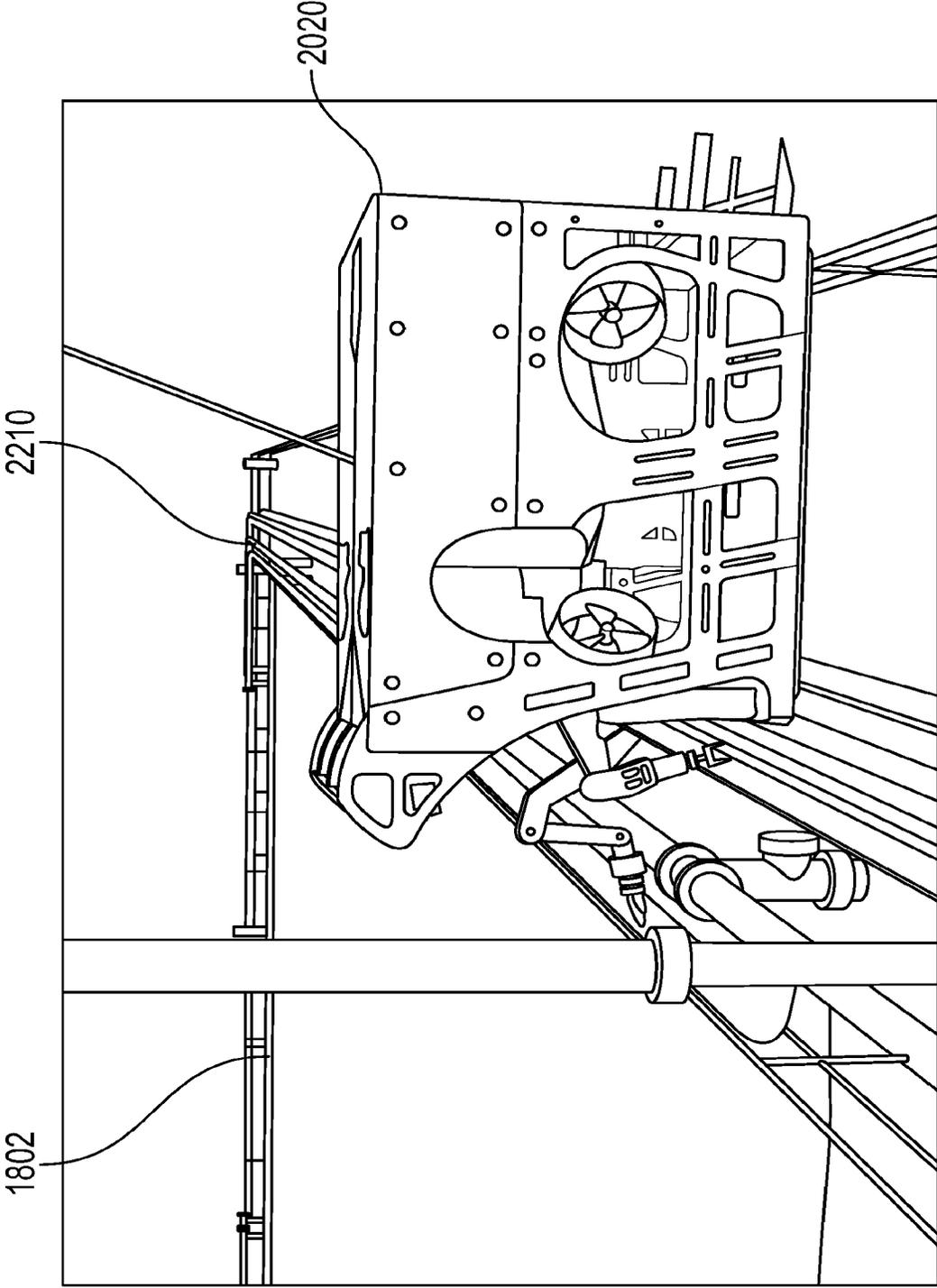


FIG. 22

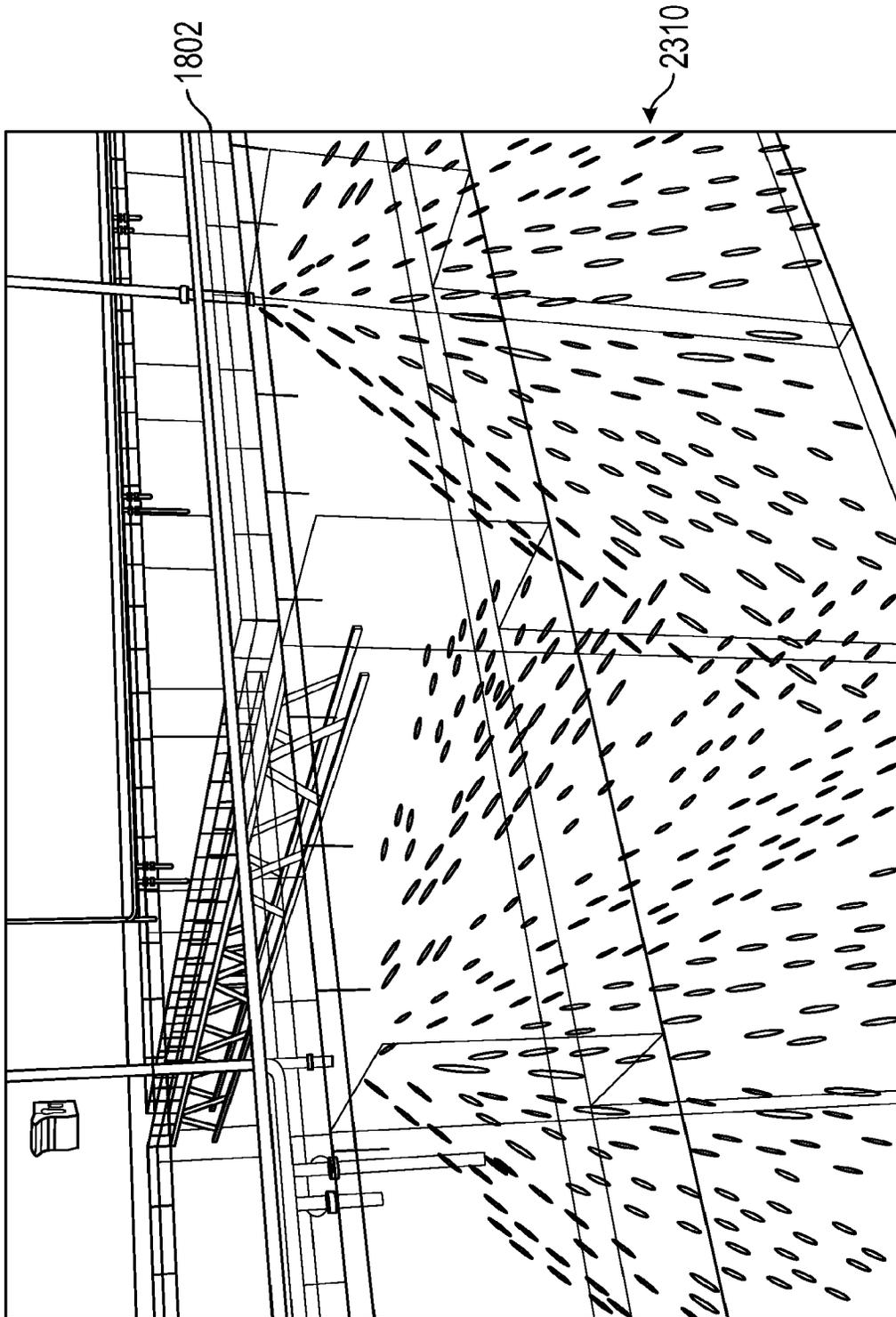


FIG. 23

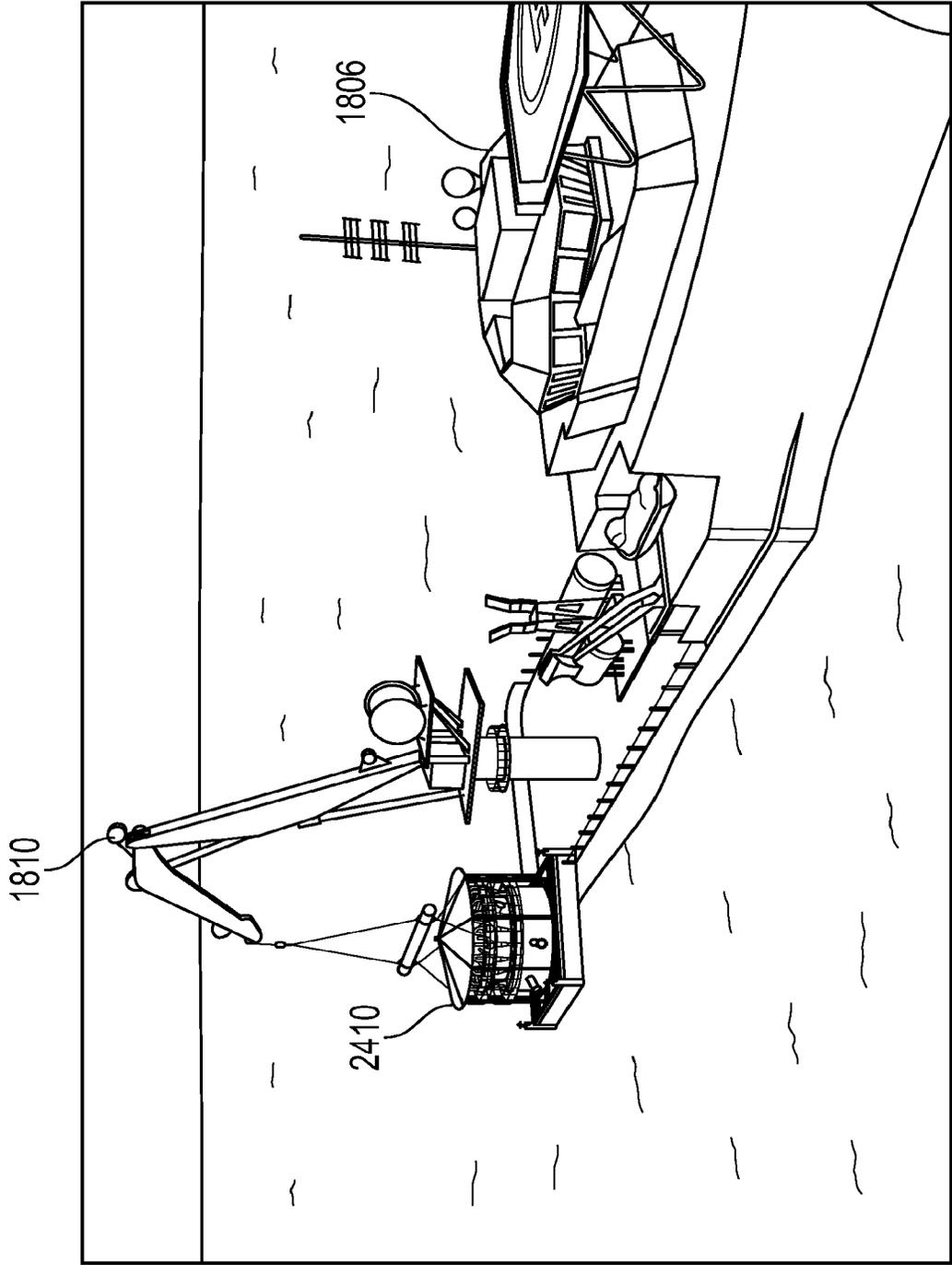


FIG. 24

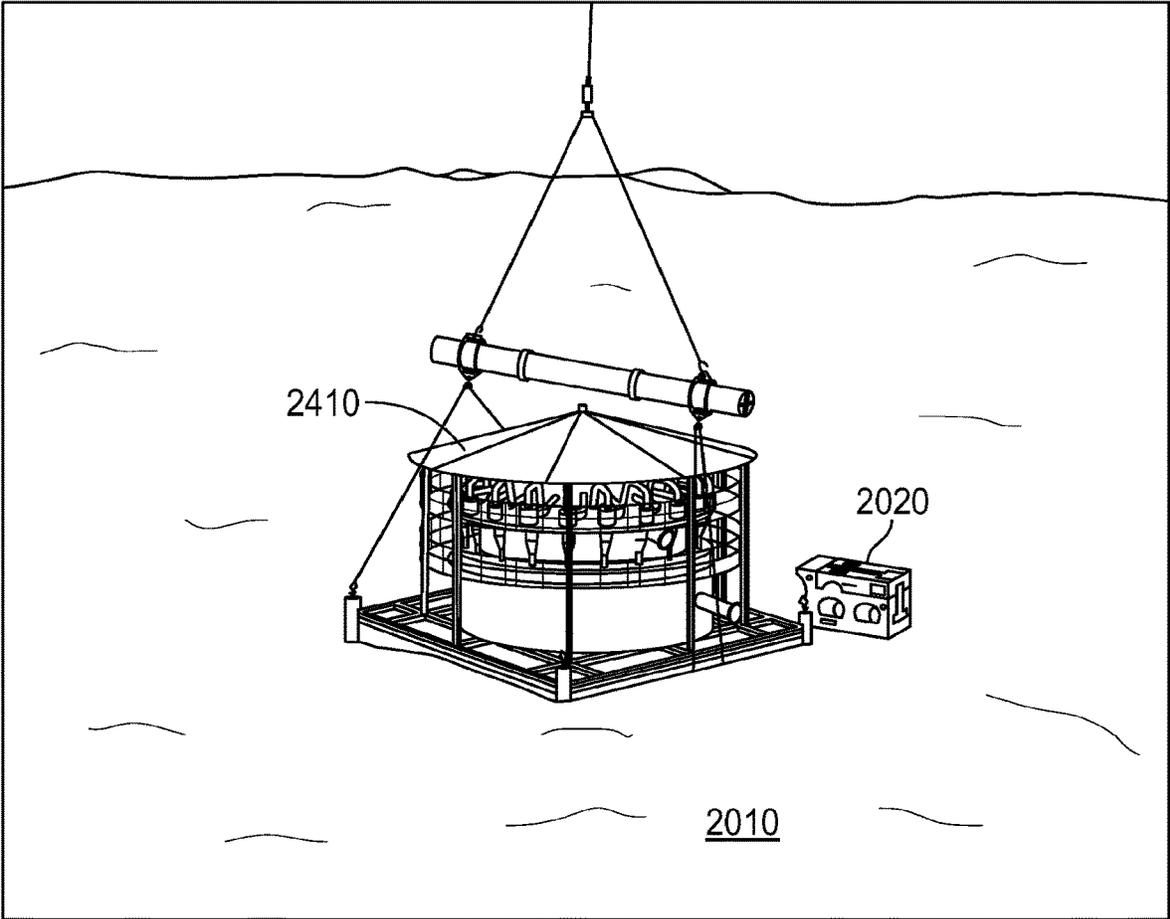


FIG. 25

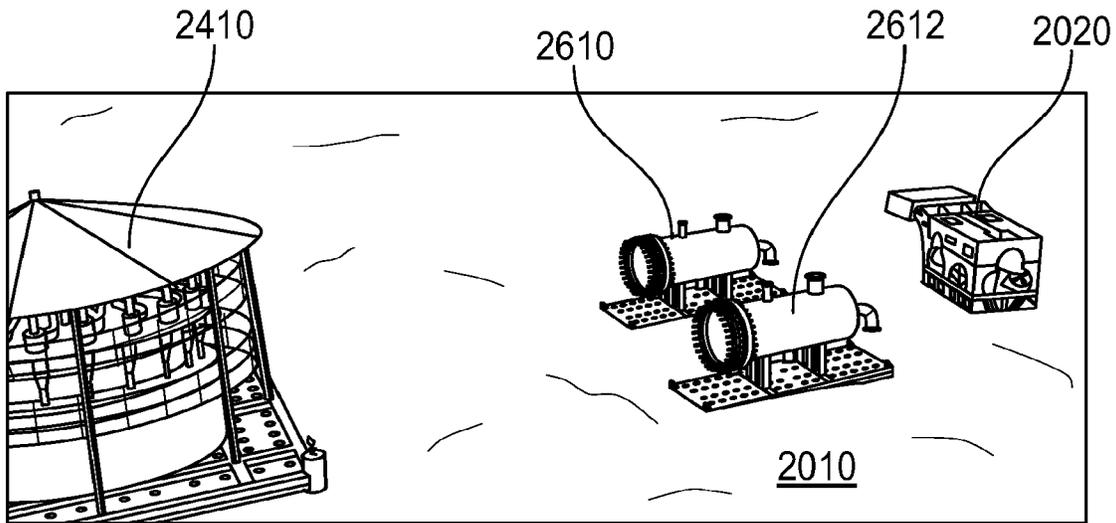


FIG. 26

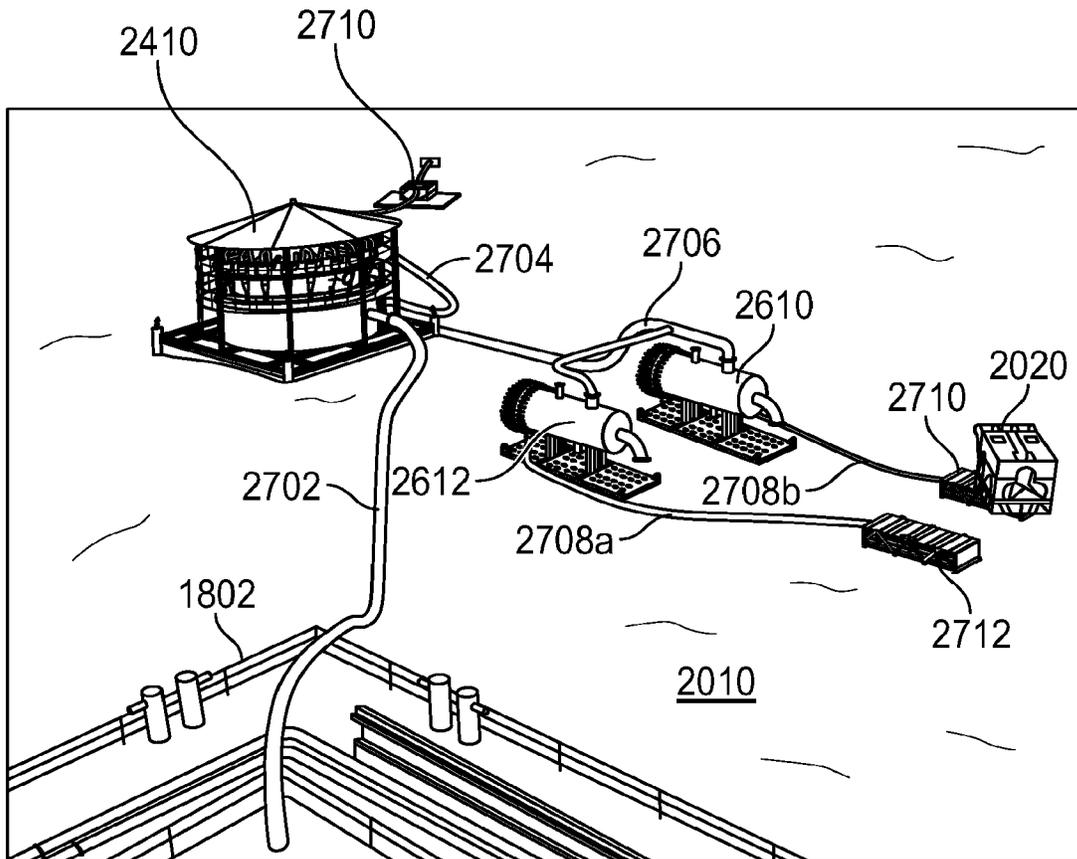


FIG. 27

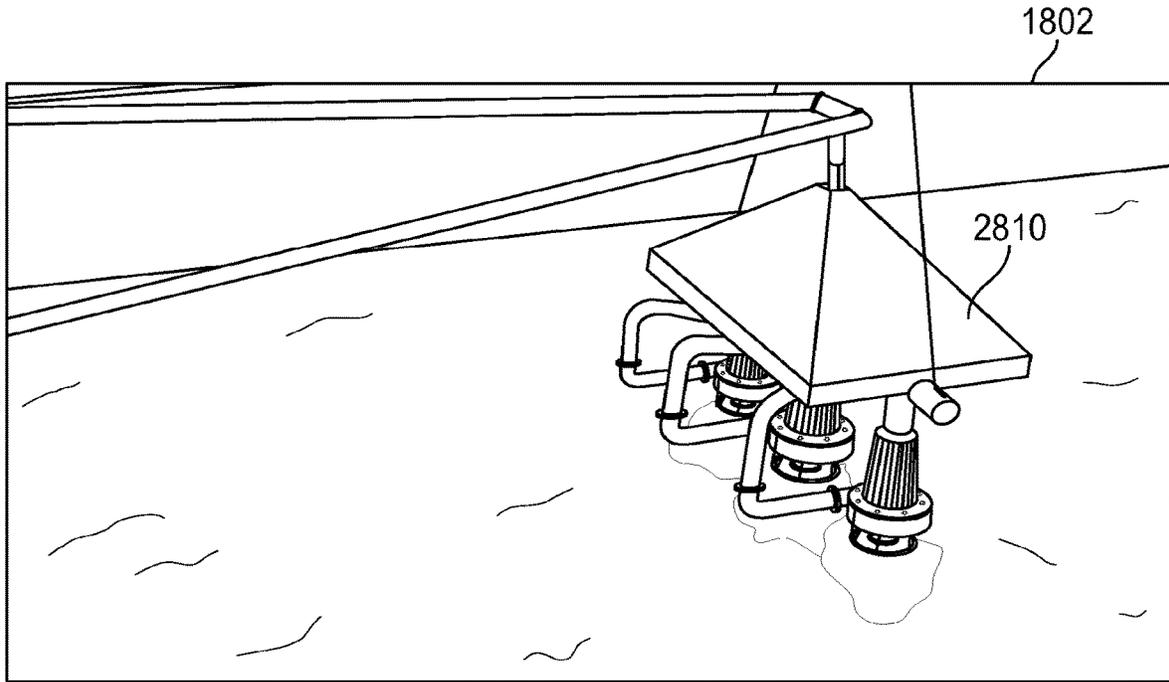


FIG. 28

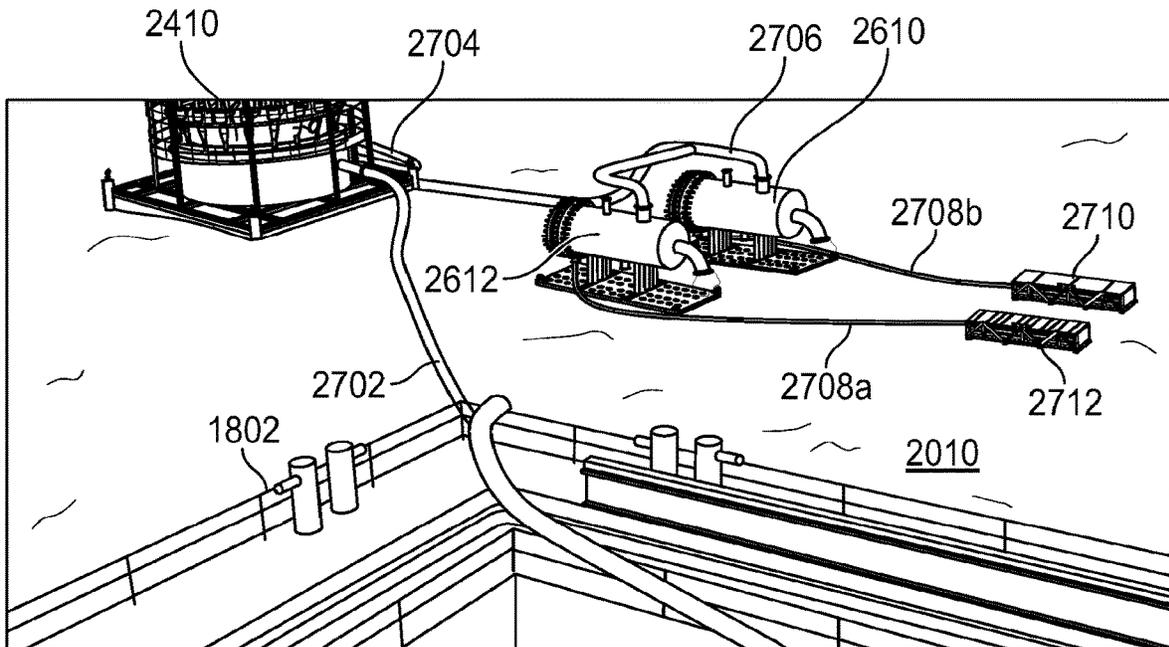


FIG. 29

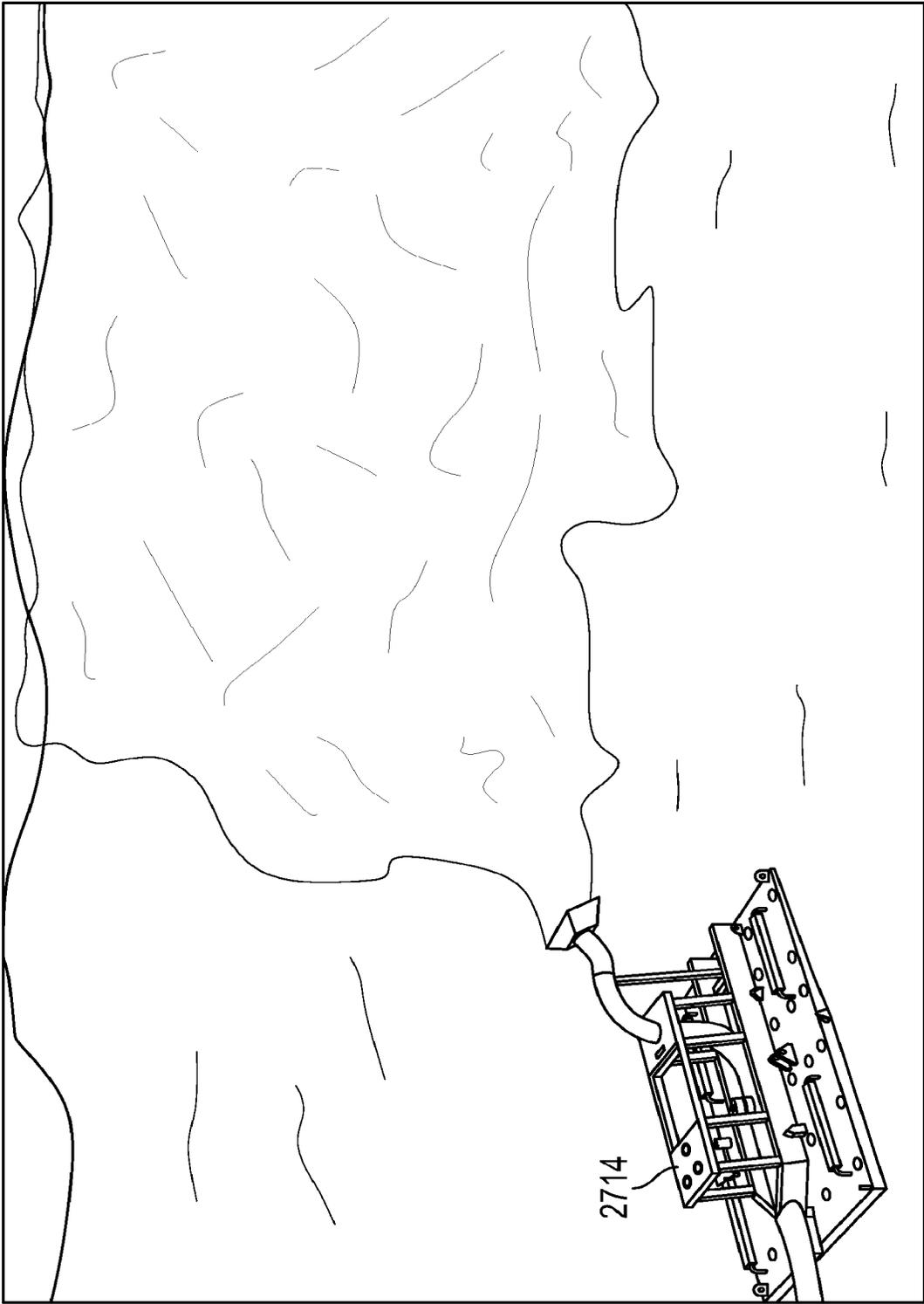


FIG. 30

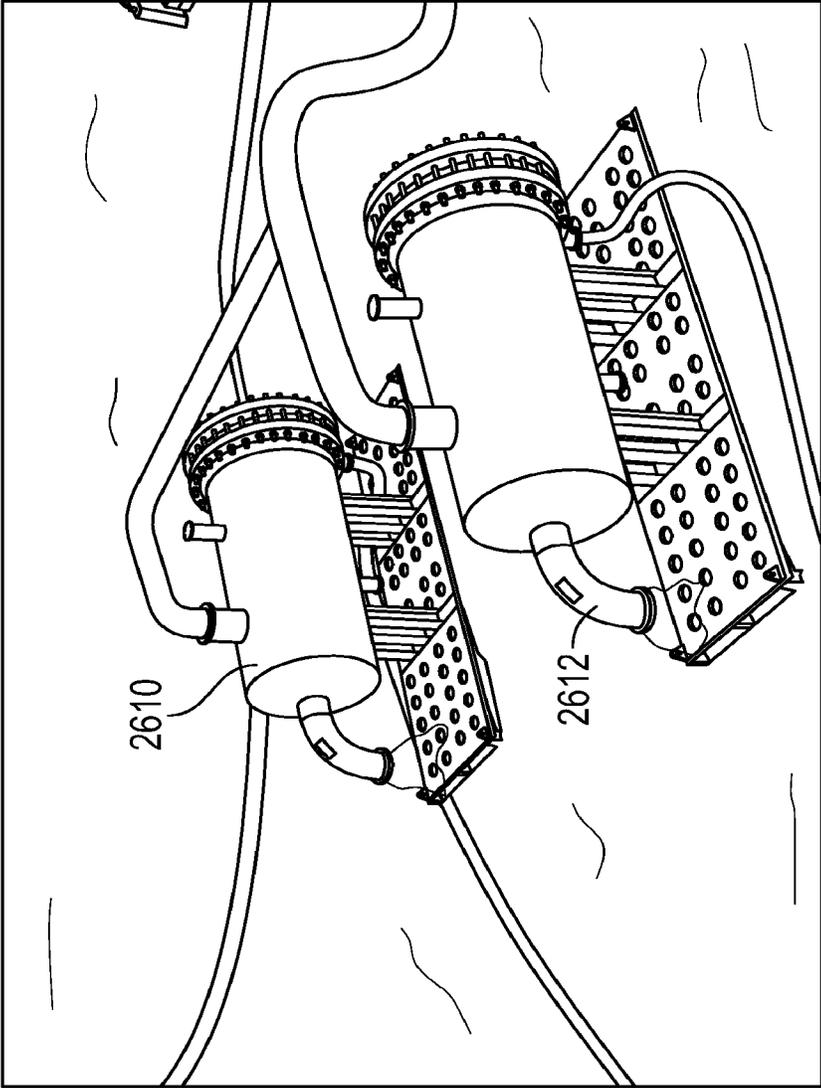


FIG. 31

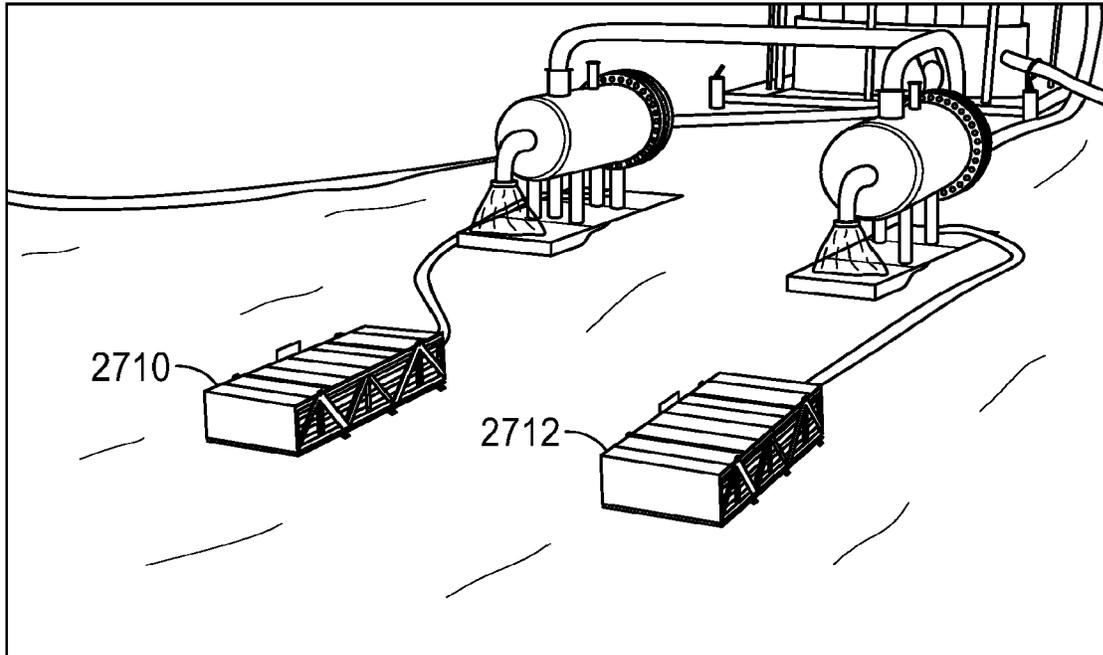


FIG. 32

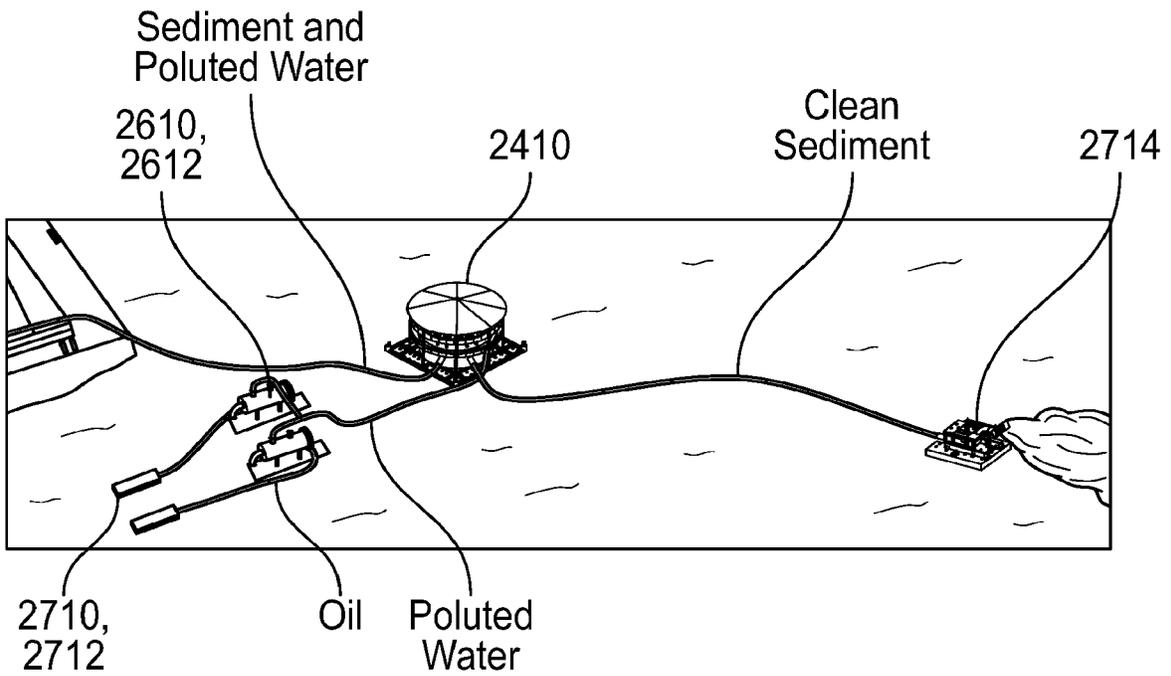


FIG. 33

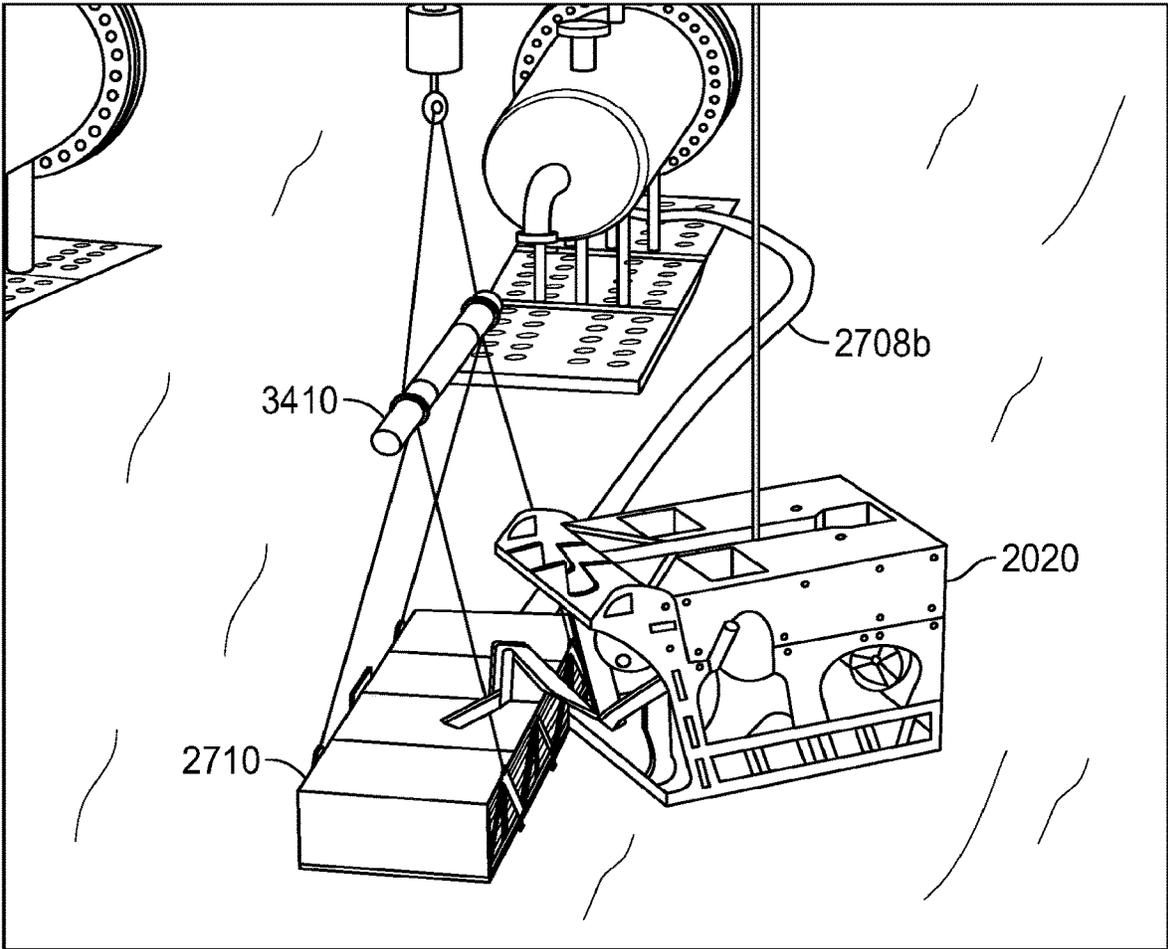


FIG. 34

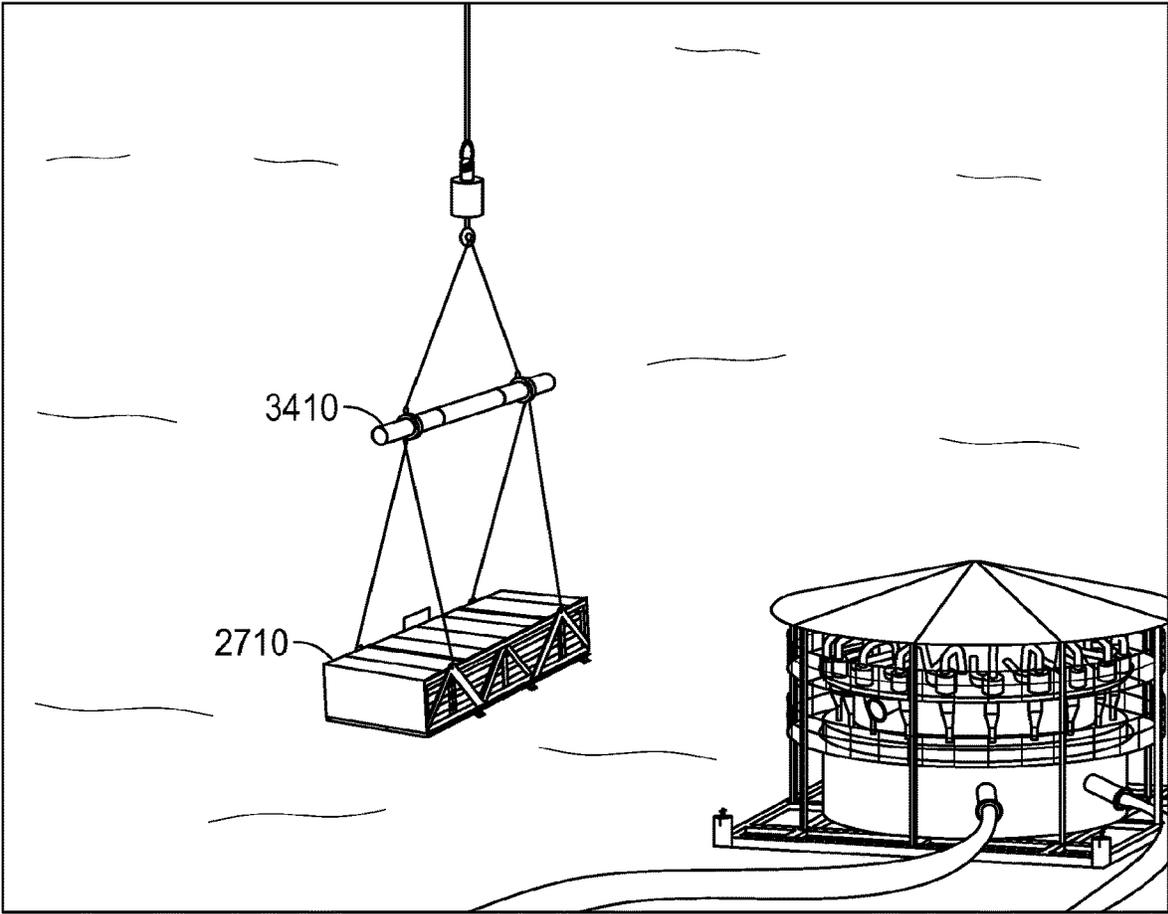


FIG. 35

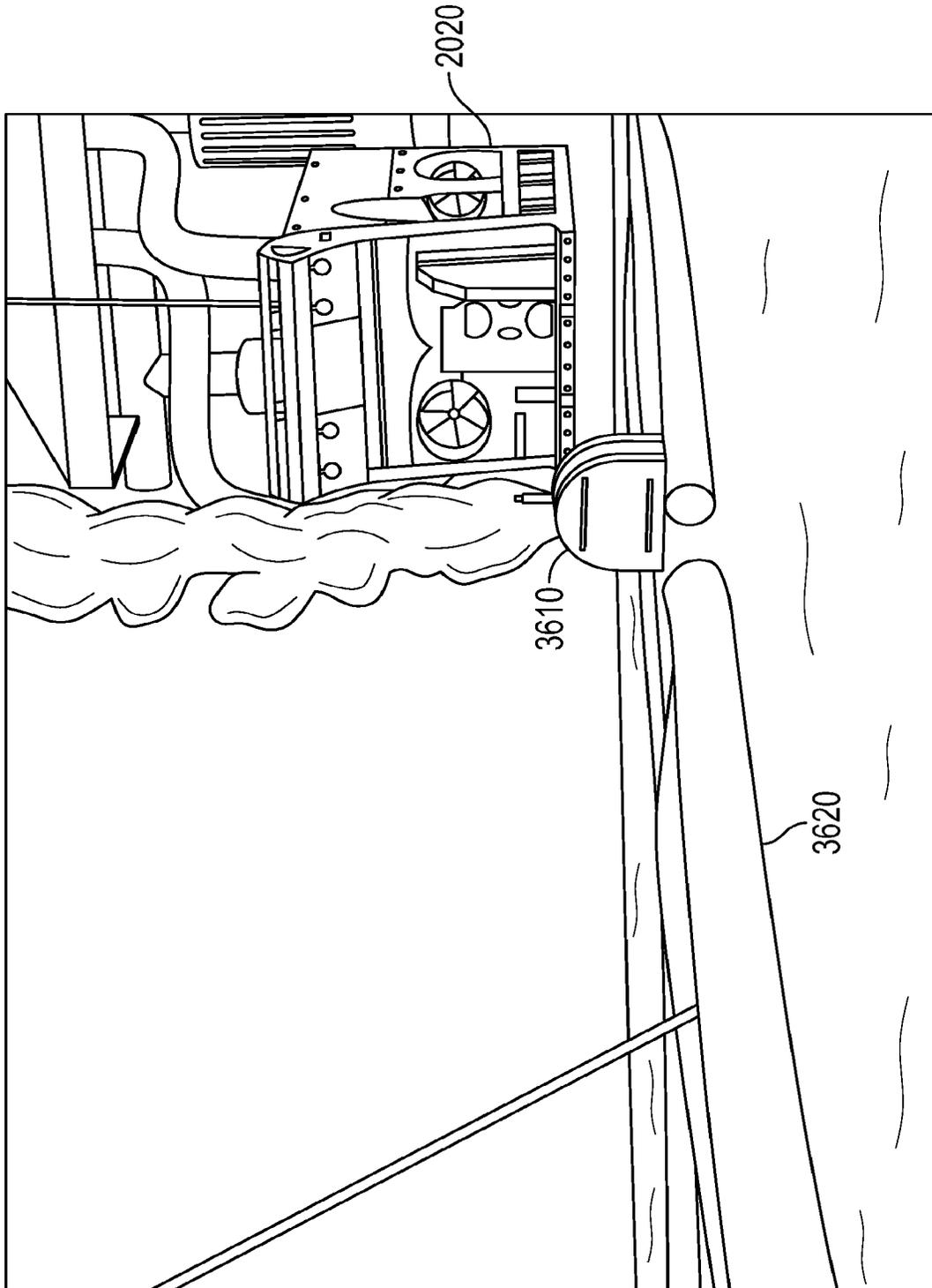


FIG. 36

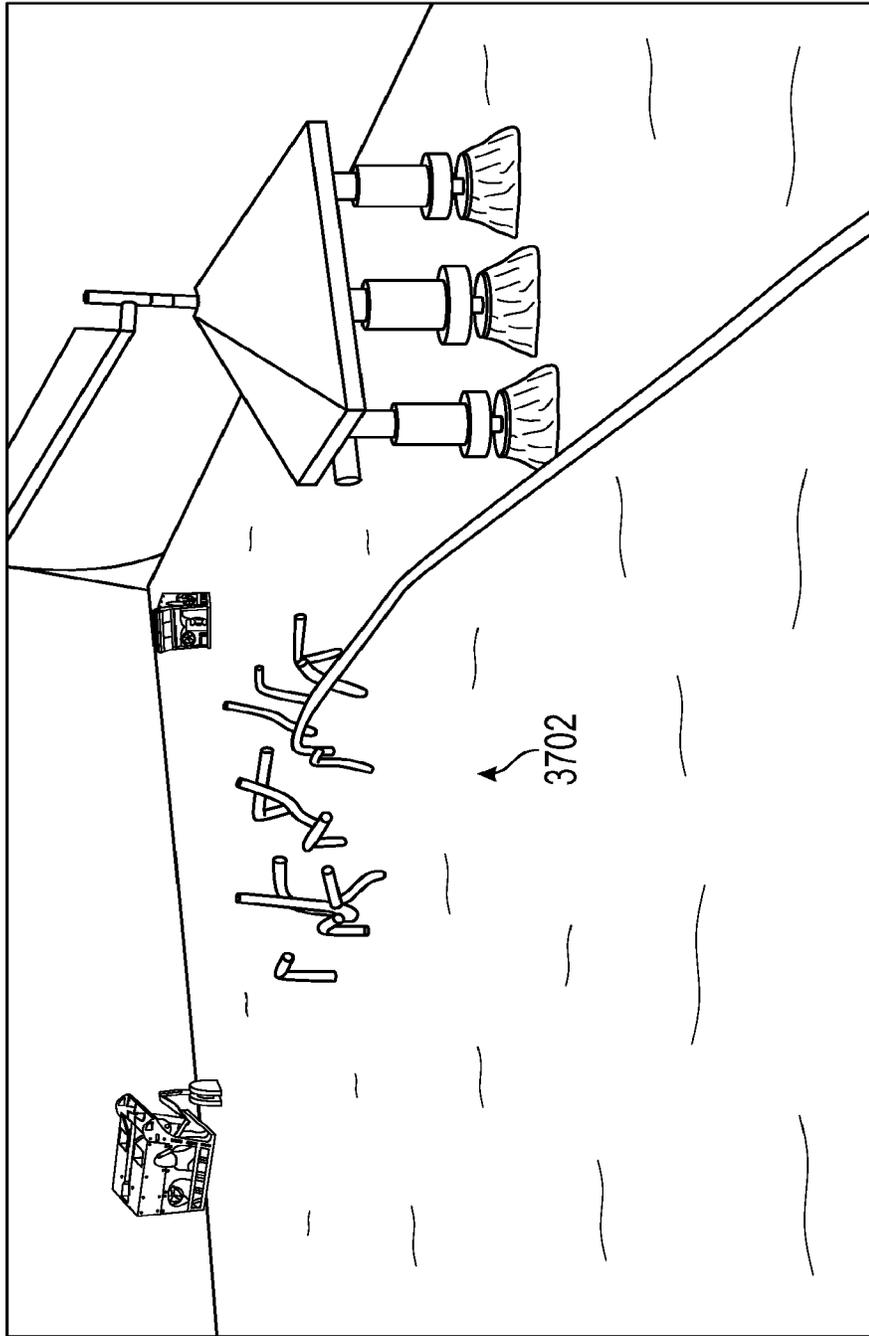


FIG. 37

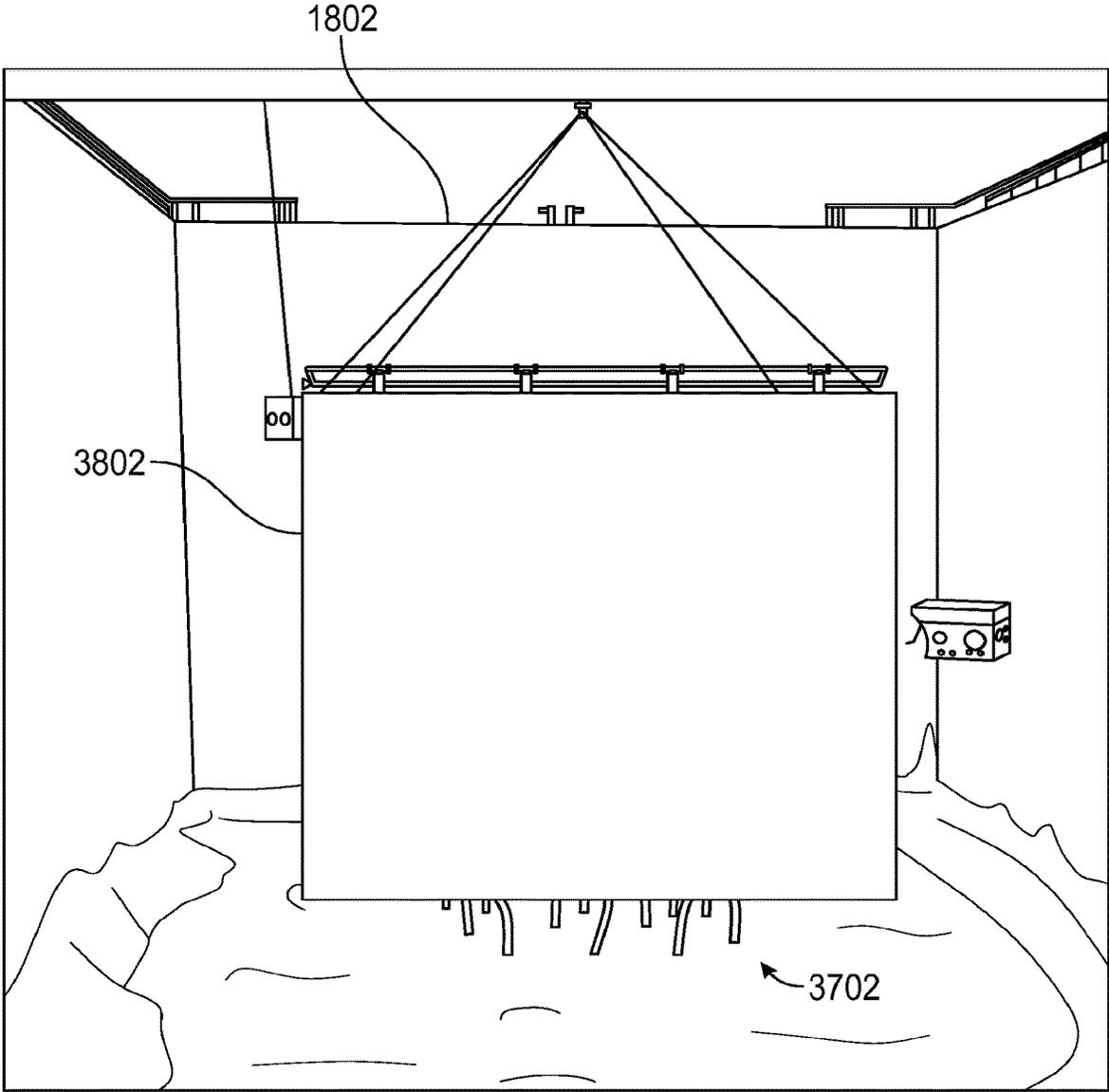


FIG. 38

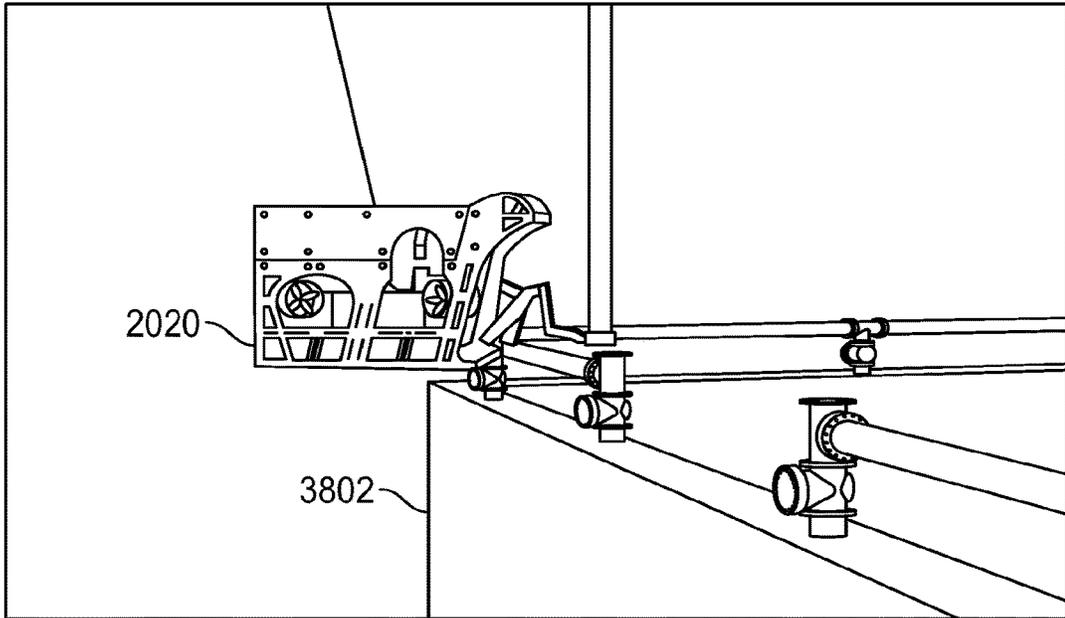


FIG. 39

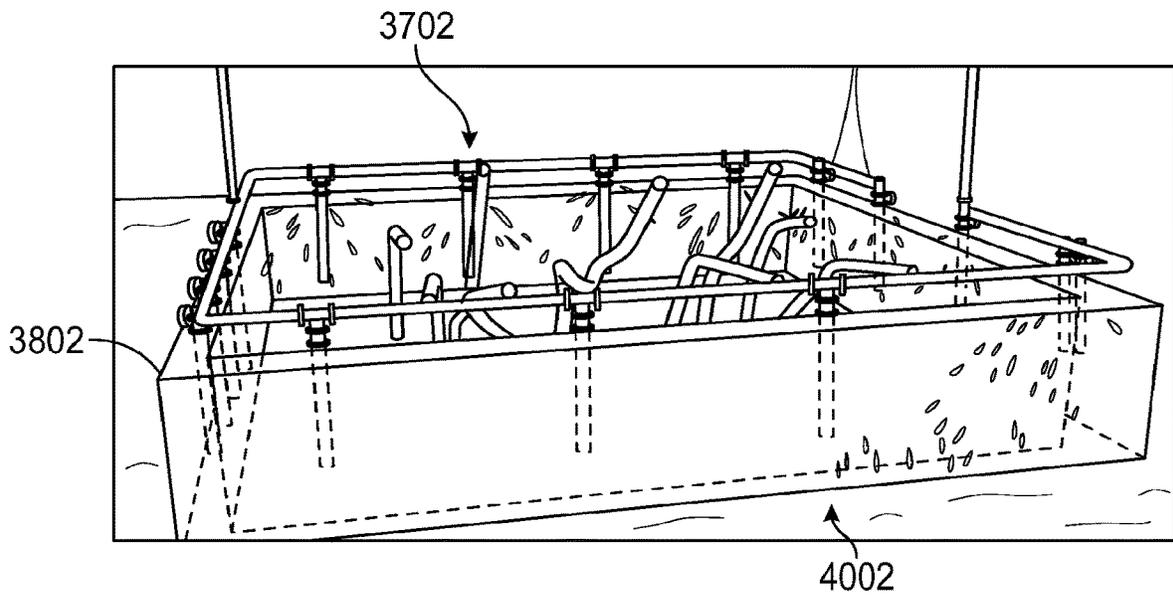


FIG. 40

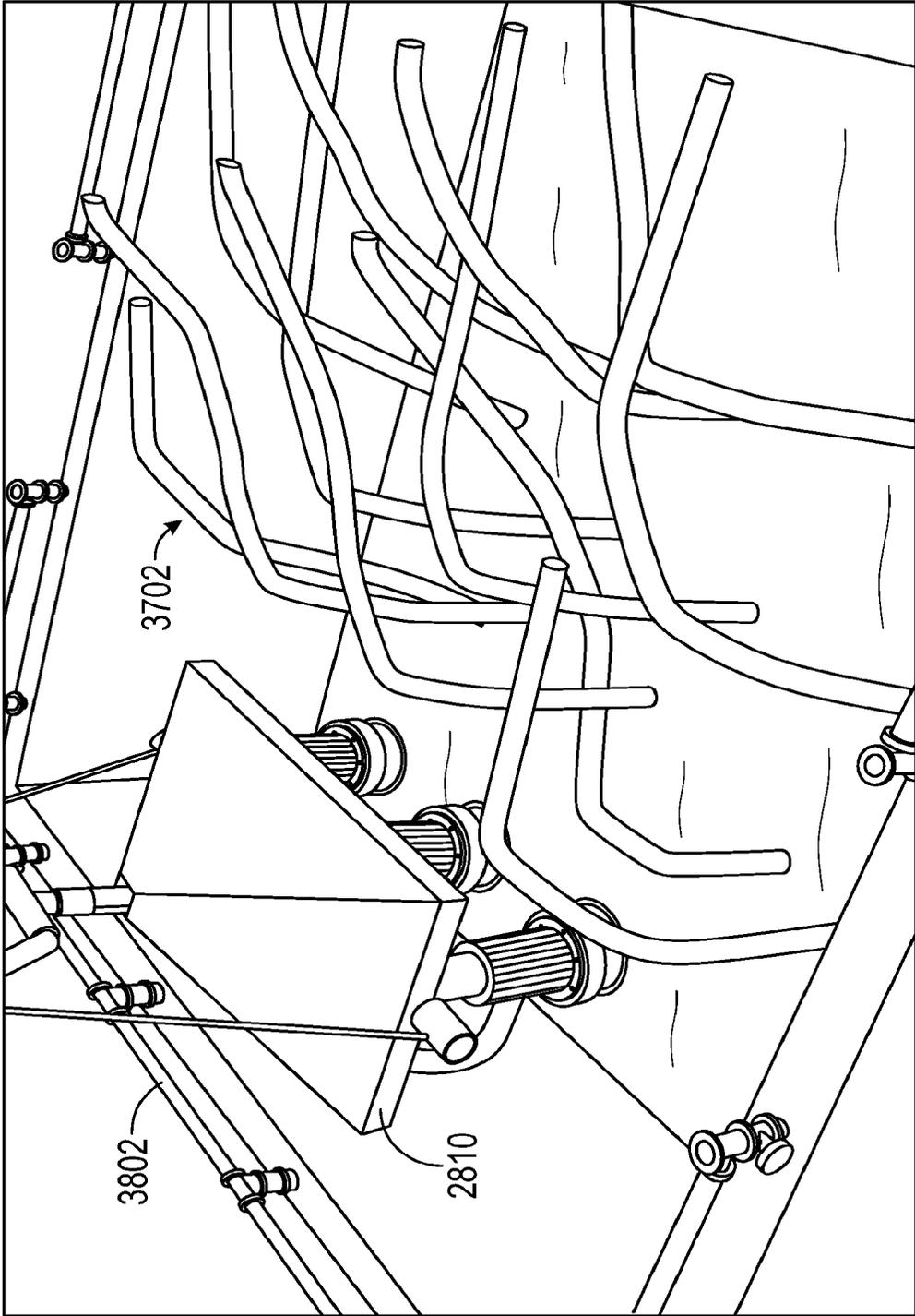


FIG. 41

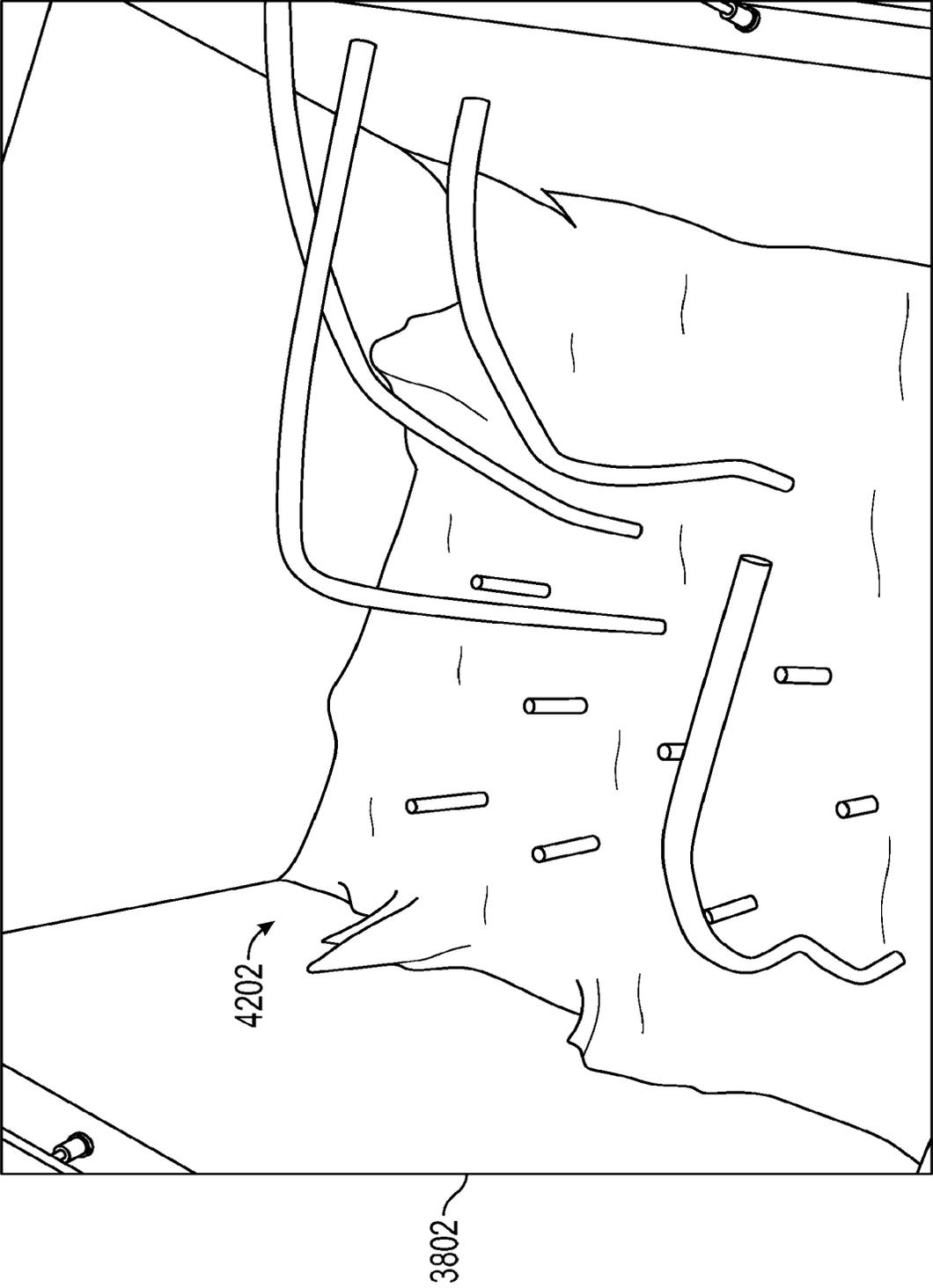
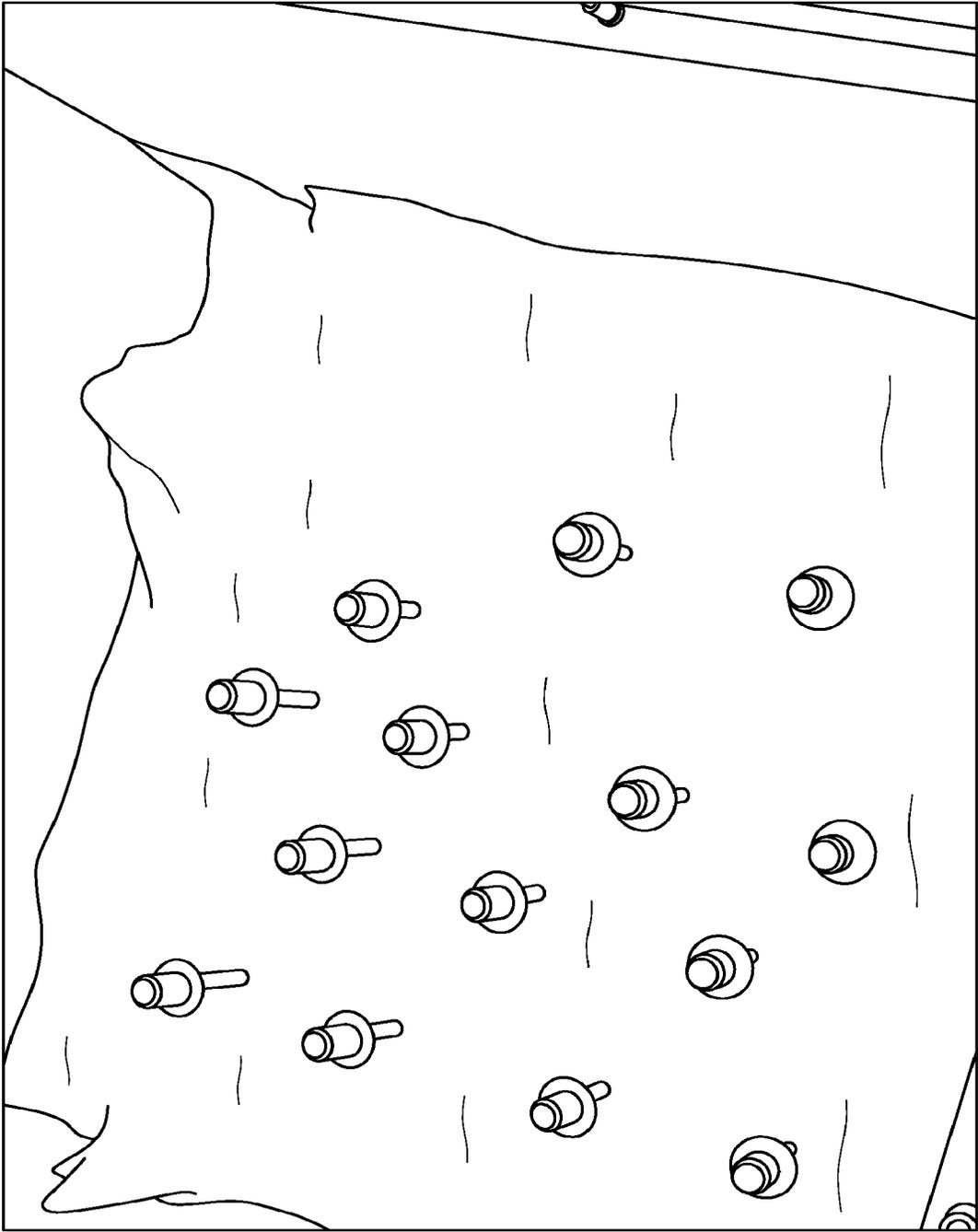


FIG. 42



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FIG. 43

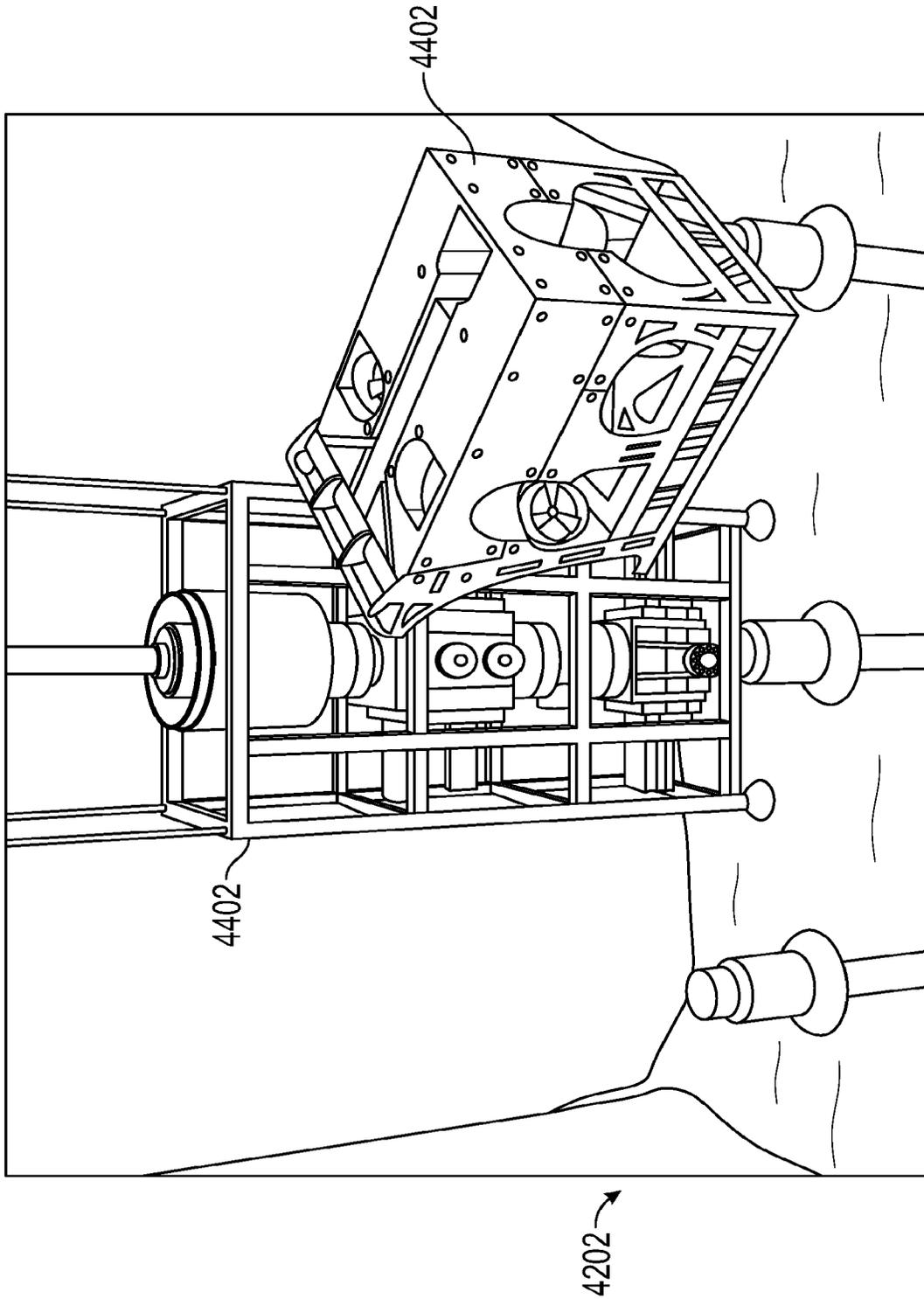


FIG. 44

## SUBSEA SEDIMENT SEPARATION AND FILTRATION SYSTEM

### CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a Divisional of U.S. patent application Ser. No. 17/395,265, filed Aug. 5, 2021, which claims the benefit of U.S. Provisional Patent Application No. 63/061,288, filed Aug. 5, 2020 and 63/062,410, filed Aug. 6, 2020, the entire contents of which are incorporated herein by reference.

### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are part of this disclosure and are incorporated into the specification. The drawings illustrate example embodiments of the disclosure and, in conjunction with the description and claims, serve to explain various principles, features, or aspects of the disclosure. Certain embodiments of the disclosure are described more fully below with reference to the accompanying drawings. However, various aspects of the disclosure may be implemented in many different forms and should not be construed as being limited to the implementations set forth herein. Like numbers refer to like, but not necessarily the same or identical, elements throughout.

FIG. 1 is a three-dimensional perspective view of a cofferdam structure including suction piles, in accordance with one or more embodiments of the disclosure.

FIG. 2 is a top view of a cofferdam structure including suction piles, in accordance with one or more embodiments of the disclosure.

FIG. 3 is a cross-sectional view of a cofferdam structure including suction piles, in accordance with one or more embodiments of the disclosure.

FIG. 4 is an enlarged cross-sectional view of an end wall of the cofferdam structure of FIG. 3, in accordance with one or more embodiments of the disclosure.

FIG. 5 is a cross-sectional view of a cofferdam structure including fluidic connections between a plurality of suction piles, in accordance with one or more embodiments of the disclosure.

FIG. 6A illustrates an end view of a cofferdam structure including suction piles in a first configuration during installation, in accordance with one or more embodiments of the disclosure.

FIG. 6B illustrates an end view of a cofferdam structure including suction piles in a second configuration during installation, in accordance with one or more embodiments of the disclosure.

FIG. 7 illustrates an end view of a cofferdam structure including suction piles in which the height of the cofferdam structure is chosen based on a thickness of a sediment layer, in accordance with one or more embodiments of the disclosure.

FIG. 8 illustrates a second cofferdam structure installed within a first cofferdam structure, in accordance with one or more embodiments of the disclosure.

FIG. 9 is a three-dimensional perspective view of a cofferdam structure including suction piles, in accordance with one or more embodiments of the disclosure.

FIG. 10 is a three-dimensional perspective view of a cofferdam structure in a partially installed configuration, according to an embodiment.

FIG. 11A is a top-down view of components of a subsea sediment separation and filtration system, according to an embodiment.

FIG. 11B is a top-down view of the subsea sediment separation and filtration system of FIG. 11A in an installed configuration, according to an embodiment.

FIG. 12A is a three-dimensional perspective view of a filtration tower held by a lifting apparatus, according to an embodiment.

FIG. 12B is a first three-dimensional perspective view of the filtration tower of FIG. 12A in an installed configuration, according to an embodiment.

FIG. 12C is a second three-dimensional perspective view of the filtration tower of FIGS. 12A and 12B in an installed configuration, according to an embodiment.

FIG. 13 is a second three-dimensional perspective view of a pressure vessel, according to an embodiment.

FIG. 14 is a three-dimensional perspective view of a bladder skid, according to an embodiment.

FIG. 15 is a three-dimensional perspective view of a spreader apparatus, according to an embodiment.

FIG. 16 is a process flow diagram for a subsea sediment separation and filtration system, according to an embodiment.

FIG. 17 is a flow chart illustrating a method of operating a subsea sediment separation and filtration system, according to an embodiment.

FIG. 18 is a first three-dimensional perspective view of a cofferdam being positioned topside, according to an embodiment.

FIG. 19 is a second three-dimensional perspective view of a cofferdam being positioned topside, according to an embodiment.

FIG. 20 is a three-dimensional perspective view of a cofferdam being positioned on a subsea surface, according to an embodiment.

FIG. 21 is a three-dimensional perspective view of a cofferdam after sinking into subsea sediment under its own weight, according to an embodiment.

FIG. 22 is a three-dimensional perspective view of an ROV attaching hoses to fluidic conduits on cofferdam, according to an embodiment.

FIG. 23 is a three-dimensional perspective transparent view illustrating fluid being drawn from the cofferdam through the fluidic conduits, according to an embodiment.

FIG. 24 is a three-dimensional perspective view of a filtration tower being lowered into the ocean by a crane on a topside vessel, according to an embodiment.

FIG. 25 is a three-dimensional perspective view of the filtration tower of FIG. 24 being positioned on a subsea surface, according to an embodiment.

FIG. 26 is a three-dimensional perspective view of pressure vessels and bladder skids being positioned on a subsea surface, according to an embodiment.

FIG. 27 is a three-dimensional perspective view of the components of the subsea sediment separation and filtration system in an assembled configuration with fluidic conduits connecting various components, according to an embodiment.

FIG. 28 is a three-dimensional perspective view of a suction system that draws water and sediment out of a region encompassed by the cofferdam, according to an embodiment.

FIG. 29 is a three-dimensional perspective view of the subsea sediment separation and filtration system, according to an embodiment.

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FIG. 30 is a three-dimensional perspective view of an operating sediment sprayer device, according to an embodiment.

FIG. 31 is a three-dimensional perspective view of an operating pressure vessel, according to an embodiment.

FIG. 32 is a three-dimensional perspective view of bladder skids in operation, according to an embodiment.

FIG. 33 is a further three-dimensional perspective view of the components of the subsea sediment separation and filtration system in an assembled configuration with fluidic conduits connecting various components, according to an embodiment.

FIG. 34 is a three-dimensional perspective view of a bladder skid being attached to a crane, according to an embodiment.

FIG. 35 is a three-dimensional perspective view of a bladder skid being raised to a topside vessel by a crane, according to an embodiment.

FIG. 36 is a three-dimensional perspective view of an ROV cutting a damaged pipe, according to an embodiment.

FIG. 37 is a three-dimensional perspective view of an ROV cutting a plurality of damaged pipes, according to an embodiment.

FIG. 38 is a three-dimensional perspective view of a smaller cofferdam being lowered over the plurality of damaged pipes, according to an embodiment.

FIG. 39 is a three-dimensional perspective view of an ROV attaching hoses to fluidic conduits on the smaller cofferdam, according to an embodiment.

FIG. 40 is a three-dimensional perspective transparent view illustrating fluid being drawn from the smaller cofferdam through the fluidic conduits, according to an embodiment.

FIG. 41 is a three-dimensional perspective view of a suction system drawing water and sediment out of a region encompassed by the smaller cofferdam, according to an embodiment.

FIG. 42 is a three-dimensional perspective view of pipes that have been further cut to ready them for repair, according to an embodiment.

FIG. 43 is a three-dimensional perspective view of pipes that have been capped, according to an embodiment.

FIG. 44 is a three-dimensional perspective view of an ROV positioning a device configured to permanently seal the damaged pipes, according to an embodiment.

#### DETAILED DESCRIPTION

This disclosure generally relates to cofferdams having suction pile anchors. A conventional cofferdam is a watertight enclosure that may be pumped dry to permit construction work below a waterline, as when building a bridge or repairing a ship. Cofferdams may also be used in sub-sea applications when sediment is needed to be removed from a subsea location. Suction piles (also known as suction caissons) are fixed platform anchors that are used as anchors for offshore installations, oil platforms, oil drilling platforms, etc. A conventional suction pile is essentially a large cylinder that is closed at one end. The structure is lowered to the ocean floor, with a downwardly facing open end, where the structure partially sinks into ocean-floor sediment of its own weight. Water is then pumped out of the structure causing a negative pressure inside the structure. The negative pressure forces the suction pile into the seabed sediment whereby the suction pile becomes strongly attached to the ocean floor and serves as an anchor. Once installed, the suction pile resists axial and lateral loads and may be used to secure mooring

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lines that are attached to the suction pile at various load points. As described in greater detail below, suction piles may be attached to a cofferdam structure or the cofferdam structure may include internal structures that may be used as suction piles to secure the cofferdam structure.

FIG. 1 is a three-dimensional perspective view of a cofferdam structure 100 including suction piles, in accordance with one or more embodiments of the disclosure. As described in greater detail below, cofferdam structure 100 includes double walls each having an open end at the bottom and a closed end at the top so that walls function as a suction pile. In this way, water may be partially or completely removed from the walls of cofferdam structure 100 so that induced negative pressure within the walls generates a net force that pushes cofferdam structure 100 into a sediment layer of the seabed. Cofferdam structure 100 may be used for deep sea operations when it is necessary to excavate sediment from an area of the sea floor for maintenance or installation of a subsea structure such as a drilling rig, an oil well, a pipeline, etc. Cofferdam structure 100 may also be used for undersea exploration, recovery of a shipwreck, recovery of sunken treasure, etc. In further embodiments, cofferdam structure 100 may be used for applications other than those requiring excavation from the sea floor. For example, cofferdam structure 100 may be used for oil/gas well decommissioning, well intervention, control and plugging of wells, abandoning wells, etc.

As illustrated in FIG. 1, cofferdam structure 100 includes four walls 102a, 102b, 102c, and 102d that form a rectangular open frame structure. Cofferdam structure 100 is characterized by a length L, a width W, and a height H. According to an embodiment, cofferdam structure 100 may have dimensions L=750 feet, W=150 feet, and H=120 to 150 feet. Walls 102a to 102d may be four-foot stud walls enclosing a hollow space in between, as described in greater detail below with reference to FIG. 4. Cofferdam structure 100 may further be configured to include an extended structure 106 (i.e., an overhang) around a top border region of cofferdam structure 100. In some embodiments, extended structure 106 may serve as a mud mat. Extended structure 106 may have height of from 20 to 50 feet and a width of approximately 20 feet. Other embodiments may have other dimensions for comparable features. Cofferdam structure 100 may further include a walkway 107 that may be used during maintenance or installation operations. Other embodiments may omit extended structure 106 and/or walkway 107.

As described in greater detail below, cofferdam structure 100 may include suction pile structures built into walls 102a, 102b, 102c, and 102d. As such, cofferdam structure 100 may be provided with suction pile equipment that is configured to allow removal of water from walls 102a, 102b, 102c, and 102d. As shown in FIG. 1, cofferdam structure 100 may include fluidic pipes or tubing 104a to 104d that may be configured to make a fluidic connection with internal spaces of walls 102a to 102d. Fluidic pipes or tubing 104a to 104d may further be connected by a manifold (not shown). An ROV may make one or more fluidic connections with fluidic pipes or tubing 104a to 104d through various pieces of suction pile equipment. In this way, an ROV may partially or completely pump water out of walls 102a to 102d. Use of an ROV, however, is only one method by which cofferdam structure 100 may be accessed, ballasted/de-ballasted, etc. In other embodiments, fluidic connections with fluidic pipes or tubing 104a to 104d of cofferdam structure 100 may be made using any suitable device such as a topside pump, a skid-mounted pump, a subsea pump, etc.

FIG. 2 is a top view of cofferdam structure 100 of FIG. 1, in accordance with one or more embodiments of the disclosure. Walls 102a to 102d enclose an open region 200. Once cofferdam structure 100 is installed on the seabed, sediment may be removed from region 200 as mentioned above. Each of walls 102a to 102d may be a double-walled structure having an inner wall 202a and an outer wall 202b. Further, the double-walled structure may be partitioned into a plurality of compartments by partition structures 204a, 204b, etc. In this way, each double-walled structure may be configured to include a plurality of hollow regions 206a, 206b, 206c, etc. Each of regions 206a, 206b, 206c, etc. may be provided with a closed top end structure 208a, 208b, 208c, etc., and a corresponding open bottom end structure (e.g., see open bottom 406 in FIG. 4). In this way, regions 206a, 206b, 206c, etc., may be configured to act as suction piles. Each of regions 206a, 206b, 206c, etc., may be fluidically coupled via fluidic pipes or tubing 104a to 104d so that water may be removed from regions 206a, 206b, 206c, etc., to thereby induce negative pressure within regions 206a, 206b, 206c, etc. Fluidic pipes or tubing 104a to 104d may further be connected by a manifold (not shown). FIG. 2 also defines a cross section 3-3 that is used to define the cross-sectional view of cofferdam structure 100 shown in FIG. 3, and described in greater detail below.

FIG. 3 is a cross-sectional view of cofferdam structure 100 including suction piles, in accordance with one or more embodiments of the disclosure. This cross-sectional view cuts through end wall 102d as shown in FIG. 4, and described in greater detail below. FIG. 3 also provides a side view of internal wall 102a. Although not shown in cross section, regions 206a, 206b, 206c, etc., of internal wall 102a are also indicated. Regions 206a, 206b, 206c, etc., are separated by internal partitions 204a, 204b, 204c, etc., to thereby form hollow spaces that may service as suction piles, as mentioned above and described in greater detail below.

FIG. 4 is an enlarged cross-sectional view 400 of end wall 102d of cofferdam structure 100 of FIG. 3, in accordance with one or more embodiments of the disclosure. End wall 102d includes an outer wall 402a and an inner wall 402b that forms a hollow space between walls 402a and 402b. Outer wall 402a is an externally facing wall and inner wall 402b faces internal region 200 (e.g., see FIG. 2). End wall 102d further includes a closed top 404 structure and an open bottom end 406. End wall 102d further includes extended structure 106, as described above. In this configuration, a suction pile is formed by a hollow region (e.g., shown as a hatched region) that includes a first hollow region of height h1 and second hollow region with in extended structure 106 having height h2. The first hollow region may have thickness d1 and the second hollow region may have thickness d2. In an example embodiment, h1=100 feet, d1=4 feet, h2=20 feet, and d2=20 feet. Other embodiments may have other dimensions for comparable features.

The suction pile of FIG. 4 (i.e., hatched region of FIG. 4) may further be provided with one or more fluidic conduits. In this example, two fluidic conduits 408a and 408b are shown. Fluidic conduits 408 may have various configurations. For example, fluidic conduit 408a may have a first length that extends into extended structure 106 and fluidic conduit 408b may have a second length. In this example, the first length is longer than the second length. In other embodiments, both fluidic conduits 408a and 408b may have a common length. Other embodiments may have greater or fewer fluidic conduits. In this example, fluidic conduits 408a and 408b are shown as perforated pipes that

are configured to allow water to flow through a plurality of apertures. Perforated pipes may be advantageous for use in water that contains mud and/or other sediment. In this regard, perforated pipes may be less prone to clogging due to mud and/or other sediment than pipes that are not perforated. Other embodiments may have fluidic conduits 408a and 408b having smooth surfaces with a single opening at a distal end of each fluidic conduit (not shown).

Fluidic conduits 408a and 408b may be fluidically coupled to suction pile equipment 410 that may allow an ROV or other external device to couple to fluidic conduits 408a and 408b. For example, a pump provided by an ROV may be configured to fluidically couple to fluidic conduits 408a and 408b and to pump water out of the suction pile structure. In other embodiments, fluidic connections with fluidic conduits 408a and 408b may be made using any suitable device such as a topside pump, a skid-mounted pump, a subsea pump, etc.

FIG. 5 is a cross-sectional view 500 of a cofferdam structure including fluidic connections between a plurality of suction piles, in accordance with one or more embodiments of the disclosure. FIG. 5 shows a view similar to that of FIG. 3 that is defined by the cross section 3-3 of FIG. 2. As with FIG. 3, the view of FIG. 5 shows an internal surface of wall 102a and a cross section of wall 102d, as described above with reference to FIG. 3. As described above with reference to FIG. 2, wall 102a includes partitions 204a, 204b, 204c, etc., that divide wall 102a into a plurality of hollow regions 206a, 206b, 206c, etc. Each of regions 206a, 206b, 206c, etc., is configured as a suction pile similar to the suction pile structure (e.g., hatched region) of FIG. 4.

In further embodiments, regions 206a, 206b, 206c, etc., may be formed by welding a plurality of rectangularly-shaped suction piles together to form wall 102a. As described above with reference to FIG. 4, each region 206a, 206b, 206c, etc., may be provided with one or more fluidic conduits. In this example, fluidic conduits 502a to 502f are shown. Each of fluidic conduits 502a to 502f provide a fluidic pathway through which water may be pumped out of the various suction pile structures formed by regions 206a, 206b, 206c, etc. Fluidic conduits 502a to 502f may be accessed individually by an ROV that provides separate fluidic connections to fluidic conduits 502a to 502f. In other embodiments, fluidic connections with fluidic conduits 502a to 502f may be made using any suitable device such as a topside pump, a skid-mounted pump, a subsea pump, etc.

Alternatively, one or more of the fluidic conduits 502a to 502f may be coupled together via one or more fluidic pipes or tubing 104a to 104d, as described above with reference to FIG. 1. Fluidic pipes or tubing 104a to 104d may further be connected by a manifold (not shown). For example, fluidic conduits 502a to 502c may be coupled via fluidic pipes or tubing 104a, while fluidic conduits 502d to 502f may be coupled via fluidic pipes or tubing 104b. Fluidic pipes or tubing 104a may be further coupled to fluidic port 504a and fluidic pipes or tubing 104b may be coupled to fluidic port 504b. Fluidic ports 504a and 504b may be configured to allow an ROV to make a fluidic connection with fluidic pipes or tubing 104a and 104b, respectively. In this way, an ROV may couple to the cofferdam structure of FIGS. 1 to 5 and to pump water from multiple suction pile structures simultaneously. In other embodiments, fluidic connections with fluidic ports 504a and 504b may be made using any suitable device such as a topside pump, a skid-mounted pump, a subsea pump, etc.

FIGS. 6A and 6B illustrate an end view of the cofferdam structure 100 of FIGS. 1 to 5 in first and second configura-

rations during installation, in accordance with one or more embodiments of the disclosure. Cofferdam structure **100** may be installed using a process that starts with cofferdam structure **100** being lowered into the ocean. Fluidic structures (not shown in FIGS. **6A** and **6B**) may be opened while cofferdam structure **100** moves through water toward the ocean floor or to a subsea surface of mud or sediment **602**. When cofferdam structure **100** comes to rest on a layer of mud or sediment **602** below a surface **606** of the ocean, water may be pumped out of cofferdam structure **100** by an ROV **604**, as shown in FIG. **6A**. In other embodiments, water may be pumped out of cofferdam structure **100** by any suitable device such as a topside pump, a skid-mounted pump, a subsea pump, etc. As described above, removal of water from cofferdam structure **100** induces negative pressure in the walls of cofferdam structure **100**. After a certain amount of water is removed from the walls of cofferdam structure **100**, fluidic ports (e.g., ports **504a** and **504b** of FIG. **5**) may be closed to make a watertight connection to thereby maintain the negative pressure that develops in the walls of cofferdam structure **100**.

Pressure of water above cofferdam structure **100** then forces cofferdam structure **100** into the layer of mud or sediment **602**. As shown in FIG. **6B**, cofferdam structure **100** may come to rest in a configuration in which extended structures **106** make contact with a surface of the mud or sediment **602** on the ocean floor. In this way, extended structures **106** may serve as a mud mat. Specific dimensions of cofferdam structure **100** may be chosen based on a particular application. For example, the height  $H$  (e.g., see FIG. **1** and related description) may be chosen based on a height of a particular thickness of mud or sediment **602** on the ocean floor, as described in greater detail below with reference to FIG. **7**.

FIG. **7** illustrates an end view of cofferdam structure **100** including suction piles in which a height  $h1$  of the cofferdam structure is chosen based on a thickness of a mud or sediment layer **602**, in accordance with one or more embodiments of the disclosure. As described above with reference to FIG. **4**, in one embodiment, cofferdam structure **100** may have a height  $h1$  that is approximately 100 feet. Such an embodiment may be advantageous for an application in which a sediment layer may have a thickness that is approximately 100 feet thick. The designation of height  $h1$  being approximately 100 feet is merely an example and does not imply any limitation, and other embodiments may have other dimensions for comparable features. In this configuration, cofferdam structure **100** may be forced down through sediment layer **602** and may come to rest on a lower layer **702** that may have increased mechanical properties (e.g., layer **702** may be a sediment layer with an increased density or layer **702** may be bedrock).

The configuration of FIG. **7** allows mud or sediment **704** to be removed (i.e., excavated) from an internal space of cofferdam structure **100**. In this example, mud or sediment **704** has been removed leaving a thickness  $h3$  of mud or sediment **704**. As described above,  $h1$  may be approximately 100 feet. The thickness  $h3$  of remaining mud or sediment **704** after excavation may be approximately 80 feet. These specific dimensions are merely an example and do not imply any limitation. Indeed, other embodiments may have other dimensions for comparable features. In order to maintain stability of cofferdam structure **100**, it may be necessary to leave a thickness  $h3$  of sediment within cofferdam structure **100** to maintain a seal that prevents material external to cofferdam structure **100** from entering cofferdam structure **100**. If additional sediment **704** needs to be removed for a

certain application, one or more additional smaller cofferdams may be installed, as described in further detail below with reference to FIG. **8**.

FIG. **8** illustrates a second cofferdam structure **800** within the first cofferdam structure **100**, in accordance with one or more embodiments of the disclosure. This embodiment makes it possible to remove more sediment than was removed in the example above (i.e., described with reference to FIG. **7**). In this regard, it may be necessary to leave at least a thickness  $h3$  of sediment to maintain stability of cofferdam structure **100**. For an operation requiring removal of additional sediment, a second cofferdam structure **800** having suction piles may be installed. As shown, this second cofferdam structure **800** may allow removal of an additional amount of sediment down to a thickness of  $h4$ . Further, the presence of second cofferdam structure **800** allows material to be removed down to a depth that is lower than the bottom of cofferdam structure **100**, as shown. In this example,  $h4$  may have a height that is in a range from approximately 0 to 80 feet. These specific dimensions are merely an example and do not imply any limitation. Indeed, other embodiments may have other dimensions for comparable features as needed for various applications.

FIG. **9** is a three-dimensional perspective view of a further cofferdam structure **900** including suction piles, in accordance with one or more embodiments of the disclosure. In contrast to the cofferdam structure **100** of FIGS. **1** to **8**, cofferdam structure **900** includes suction piles **902a** to **902d** attached to a frame structure that includes four walls **904a** to **904d**. In this regard, suction piles **902a** to **902d** and walls **904a** to **904d** may be steel structures that are fastened together. For example, walls **904a** to **904d** may be welded together to form a rectangular frame structure. In further embodiments, walls **904a** to **904d** may be attached to one another using various fasteners, such as bolts, rivets, etc. Further, suction piles **902a** to **902d** may be attached to walls **904a** to **904d** by welding or may be attached using various fasteners, such as bolts, rivets, etc. In other embodiments, suction piles **902a** to **902d** and walls **904a** to **904d** may be made of any other suitable structural material.

FIG. **9** illustrates an embodiment in which suction piles **902a** to **902d** are attached to corners of a rectangular frame structure that includes walls **904a** to **904d**. Further embodiments may include many different configurations of walls and suction piles. For example, the frame structure need not be a rectangular structure as shown in FIG. **9**, but rather, may be a circle, an oval, a square, a triangle, a pentagon, a hexagon, or other multi-sided polygon. In additional embodiments, the frame structure may take any shape (e.g., a shape of a ship) as needed for a particular application. Further embodiments may include greater or fewer suction piles. For example, although FIG. **9** is shown with four circular suction piles **902a** to **902d**, other embodiments may have one, two, three, five, six, etc., suction piles. Further, suction piles need not have a cylindrical shape as shown in FIG. **9**. In other embodiments, suction piles may have a rectangular shape, a square shape, a triangular shape, a pentagonal shape, a hexagonal shape, or may be another multi-sided polygon. Further, suction piles need not be attached to external surfaces of the rectangular frame structure of FIG. **9** but may be attached on internal surfaces, may be attached on a mixture of internal and external surfaces, or may be configured to be part of internal structures of cofferdam structure **900**, as was the case with the embodiments described above with reference to FIGS. **1** to **8**.

FIG. **10** is a three-dimensional perspective view **1000** of a cofferdam structure **1002** in a partially installed configura-

ration, according to an embodiment. As described above with reference to FIGS. 6A and 6B, cofferdam structure **1002** has been lowered to a subsea surface containing mud and/or sediment **1004**. Fluidic conduits **1006a**, **1006b**, **1006c**, and **1006d** may be connected to hoses **1008a**, **1008b**, **1008c**, and **1008d**, which may in turn be connected with pumps provided by one or more ROVs **1010a** and **1010b**. Alternatively, hoses **1008a**, **1008b**, **1008c**, and **1008d** may be connected to pumps, e.g., provided on a topside vessel. Fluid may be removed from cofferdam structure **1002** via hoses **1008a**, **1008b**, **1008c**, and **1008d** to thereby generate a negative pressure within cofferdam structure **1002**. The induced negative pressure with cofferdam structure **1002** generates a net force on cofferdam structure **1002** due to the weight of water above cofferdam structure **1002**, as described in greater detail above. The net force on cofferdam structure **1002** causes cofferdam structure **1002** to be forced into the layer of mud or sediment, as described above with reference to FIGS. 6A and 6B.

View **1000** of FIG. **10** also shows various exposed conductors **1012**. Conductors **1012** may be broken pipes associated with a damaged subsea oil well. In this regard, conductors **1012** may pose an environmental threat by leaking oil into the mud, sediment, and surrounding water. Disclosed systems and methods may be used for reclamation and remediation of such damaged subsea structures and surrounding water, mud, and sediment.

FIGS. **11A** and **11B** provide top-down views of a subsea sediment separation and filtration system **1100**, according to an embodiment. A topside vessel **1102** having a crane may be used to lower various components of the system **1100** to the subsea surface (e.g., subsea surface **1004**, see FIG. **10**) in proximity to cofferdam structure **1002**. In this example, the system includes four sub-systems **1104a**, **1104b**, **1104c**, and **1104d**. Each sub-system **1104a**, **1104b**, **1104c**, and **1104d** includes a filtration tower **1106**, one or more pressure vessels **1108**, and one or more bladder skids **1110**. Filtration tower **1106** receives a mixture of fluid and sediment that may be contaminated with oil. Filtration tower **1106** may include one or more filtering or separating devices, e.g., hydrocyclones, cross-flow filters, conventional filters, or sieves, that separate the mixture into a clean sediment component and a fluid component. The fluid component may be a mixture of seawater and oil. Pressure vessels **1108** may receive the liquid component and separate the oil from the water. The oil component may be safely recovered and stored in the bladder skids **1110**. The cleaned seawater component and the cleaned sediment component may then be safely returned to the surrounding subsea environment.

The filtration tower **1106** may include a set of sieves to remove large particles of the sediment component from the fluid component. In the example the fluid component may be fed through hydrocyclones, cross-flow filters, or conventional filters to further separate small particles of the sediment component from the fluid component. Filters may include activated charcoal filters, paper filters, diatomaceous earth filters, and filters made from other media.

FIG. **11B** shows the various components of the system **1100** in an installed configuration in proximity to cofferdam structure **1002**. In this example, a configuration of sub-system **1104a** is described in detail. Remaining sub-systems **1104b**, **1104c**, **1104d**, are similarly configured. Sub-systems **1104a** to **1104d** are configured to perform a dredging operation to remove a mixture of water and sediment **1004** from a region surrounded by cofferdam structure **1002**. In this regard, system **1100** includes pumps (not shown) that cause suction in a conduit **1112** which is connected to an inlet of

filtration tower **1106**. The suction in conduit **1112**, in turn, draws the water/sediment **1004** mixture from the region encompassed by cofferdam structure **1002**, through conduit **1112**, and into filtration tower **1106**. One or more filtering or separating devices (e.g., sieves, hydrocyclones, cross-flow filters, or conventional filters) within filtration tower **1106** act to separate the water/sediment **1004** mixture into a clean sediment component and a fluid component. The clean sediment component processed by filtration tower **1106** may be returned to a subsea environment via a further conduit **1114** connected to a sediment output of filtration tower **1106**. The separated fluid component (e.g., water/oil mixture) may be removed from a fluid output of filtration tower **1106** via a further conduit **1116**.

Conduit **1116** may then provide the fluid component to the one or more pressure vessels **1108** for further processing. Pressure vessels **1108** may then separate the fluid component into a first component including clean seawater and a second component containing oil. The first component including clean seawater may then be safely returned to a subsea environment via a water outlet of pressure vessels **1108**, as described in greater detail below. The second component including oil may then be provided to the one or more bladder skids **1110** via one or more further conduits **1118**. Various components of the system are described in greater detail below.

FIG. **12A** is a three-dimensional perspective view of an exemplary filtration tower **1106** held by a lifting apparatus **1210**, according to an embodiment. Filtration tower **1106** includes an inlet **1202** and first **1204a** and second **1204b** outlets. Inlet **1202** is configured to receive the water/sediment mixture which is drawn into filtration tower **1106** via pumps (not shown) within or external to the filtration tower **1106**. Outlet **1204a** is configured to provide the clean separated sediment component as output, and outlet **1204b** is configured to provide the fluid component as output. As shown, filtration tower **1106** includes a platform **1206**. In this example, platform **1206** measures 40 ft×40 ft. Other embodiments may include platforms having other dimensions suitable to other applications.

Filtration tower **1106** may be installed by connecting chains/cables **1208**, etc., to platform **1206**, as shown. Platform **1206** may then be lifted by a crane that may make a removable connection to lifting apparatus **1210**. In this way, filtration tower **1106** may be lowered to a subsea surface, wherein platform **1206** may come to rest on the subsea surface.

FIGS. **12B** and **12C** show first and second three-dimensional perspective views of an example filtration tower **1106** in an installed configuration, according to an embodiment. FIG. **12B**, for example, shows filtration tower **1106** in an exemplary orientation as if positioned on a subsea surface after being lowered to the subsea surface by lifting apparatus **1210** connected to chains/cables **1208**, as described above (e.g., see FIG. **12A**). As shown, filtration tower **1106** may include a plurality of filtering or separating devices **1212**. Examples of filtering or separating devices include hydrocyclones, sieves, cross-flow filters, conventional filters, or other types of separation devices. Filtration tower **1106** may further include a pollution dome **1214**. Pollution dome **1214** may be configured to collect any leaking oil from the environment surrounding filtration tower **1106**.

FIG. **12C** shows a cutaway view in which a portion of pollution dome **1214** has been removed. In this view of the example filtration tower **1106**, the plurality of filtering or separating devices **1212** are shown. The plurality of filtering or separating devices **1212** may be configured to have

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parallel fluidic connections between inlet **1202** and outlets **1204a** and **1204b**. In this regard, inlet **1202** may provide the water/sediment mixture to inlets of each of the plurality of filtering or separating devices **1212** via parallel fluidic connections. Similarly, outlets **1204a** and **1204b** may be connected via parallel fluidic connections to respective outlets of each of the plurality of filtering or separating devices **1212**.

FIG. **13** is a three-dimensional perspective view of pressure vessel **1108**, according to an embodiment. Pressure vessel **1300** includes an inlet **1302** and at least two outlets **1304a** and **1304b**. Inlet **1302** is configured to receive the oil/water mixture from filtration tower **1106** via conduit **1116** (e.g., see FIG. **11B**), as described above. Pressure vessel **1300** includes a filtration or separation device (e.g., a high pressure hydrocyclone device) that separates the oil/water mixture into a first component, including cleaned seawater, and a second component, including separated oil. The cleaned seawater of the first component may be safely returned to a subsea environment of pressure vessel **1108** via outlet **1304a**. The separated oil of the second component may be provided to conduits **1118** (e.g., see FIG. **11B**) via outlet **1304b**. As shown, pressure vessel **1300** may include a platform **1306**. In this example, platform **1306** measures 9.5 ft×30 ft. Other embodiments may include platforms having other dimensions suitable to other applications.

FIG. **14** is a three-dimensional perspective view **1400** of bladder skid **1110**, according to an embodiment. Bladder skid **1110** may be configured to receive the separated oil component from pressure vessel **1108** that is provided by outlet **1304b** (e.g., see FIG. **13**) via conduit **1116** (e.g., see FIG. **11B**). In this example, bladder skid measures 6 ft×15.5 feet. Other embodiments may include bladder skids having other dimensions suitable to other applications. Bladder skid **1110** may be configured to hold oil recovered by pressure vessel **1108**. Oil held in bladder skid **1110** may then be transported topside by a ROV. Alternatively, various conduits or hoses may be connected to bladder skid **1110**. Such conduits or hoses (not shown) may be used to transport oil from bladder skid **1110** to a topside vessel via one or more pumps.

FIG. **15** is a three-dimensional perspective view of a spreader apparatus **1500**, according to an embodiment. Spreader apparatus **1500** may be connected via conduit **1114** to outlet **1204a** of filtration tower **1106** (e.g., see FIGS. **11B**, **12A**, and **12B**). As such, spreader apparatus **1500** is configured to receive the clean sediment component from filtration tower **1106** and to disperse the clean sediment back to a subsea environment of spreader device **1500** via an outlet **1502**. As shown, outlet **1502** may have a flared configuration, according to an embodiment. In this way, clean sediment may be dispersed over a range of angles determined by the shape and configuration of outlet **1502**. In this example, spreader apparatus **1500** includes a platform **1504**. In this example, platform **1504** measures 24 ft×24 ft. Other embodiments may include platforms having other dimensions suitable to other applications.

FIG. **16** is a process flow diagram **1600** for a subsea sediment separation and filtration system, according to an embodiment. As described above, the system includes filtration tower **1106**, one or more pressure vessels **1108**, one or more bladder skids **1110a** and **1110b**, and spreader apparatus **1500**. The process begins by introducing a water/oil/sediment mixture into filtration tower **1106** along a first flow path **1602**. Flow path **1602** may include, for example, conduits **1112**, as illustrated in FIG. **11B**. Filtration tower **1106** separates the water/oil/sediment mixture into a first

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component containing cleaned sediment and a second component containing a water/oil mixture. The first component containing the cleaned sediment is provided to spreader apparatus **1500** along a second flow path **1604**. Flow path **1604** may include, for example, conduits **1114**, as illustrated in FIGS. **11B** and **15**. Spreader apparatus **1500** then disperses the cleaned sediment back to the subsea environment via flow path **1606**, which may include outlet **1502** (see FIG. **15**).

The second component containing the water/oil mixture is provided to the one or more pressure vessels **1108** along flow path **1608**. Flow path **1608** may include, for example, outlet **1204b**, conduits **1116**, and inlet **1302**, as illustrated in FIGS. **11B**, **12A**, **12B**, and **13**. Pressure vessel **1108** then separates the water/oil mixture into a cleaned seawater component and an oil component. The cleaned seawater component is then returned to the subsea environment along flow path **1610**. Flow path **1610** may include, for example, outlet **1304a**, as illustrated in FIG. **13**. The oil component is then provided to the one or more bladder skids **1110a** and **1110b** along flow path **1612**. Flow path **1612** may include, for example, outlet **1304b** and conduits **1118**, as illustrated in FIGS. **11B** and **13**. The oil component may then be stored in bladder skids **1110a** and **1110b**. As described above, the oil component in bladder skids **1110a** and **1110b** may subsequently be recovered by an ROV or by pumping the oil from bladder skids **1110a** and **1110b** through various conduits/hoses to a topside vessel.

FIG. **17** is a flow chart **1700** illustrating a method of operating a subsea sediment separation and filtration system **1100** (e.g., see FIGS. **11A** and **1B**), according to an embodiment. In stage **1702**, a mixture of water, sediment, and oil is dredged from a subsea sediment layer within a region encompassed by suction pile cofferdam **1002** (e.g., see FIG. **10**). The mixture is then introduced to a filtration system such as filtration tower **1106** (e.g., see FIGS. **12A** to **12C**). In stage **1704**, the method includes separating the mixture into a first component containing cleaned sediment and a second component containing an oil/water mixture. As described above, the separation in stage **1704** may be performed by filtration tower **1106**. In stage **1706**, the method includes dispersing the cleaned sediment of the first component back to the subsea environment. As described above, a spreader apparatus such as spreader apparatus **1500** (e.g., see FIG. **15**) may be used to disperse the cleaned sediment.

In stage **1708**, the method includes separating the second component containing the oil/water mixture into a cleaned seawater component and an oil component. As described above, the separation of stage **1708** may be performed by one or more pressure vessels **1108a** and **1108b** (e.g., see FIGS. **13** and **16**). In stage **1710**, the method includes returning the cleaned seawater component to the subsea environment. As described above, stage **1710** may be performed by returning the cleaned seawater component to the subsea environment through an outlet (e.g., outlet **1304a** in FIG. **13**) of the one or more pressure vessels **1108** (e.g., see FIGS. **13** and **16**). In stage **1712**, the method includes storing the separated oil component. As described above, the separated oil component may be stored in one or more bladder skids **1110a** and **1110b** (e.g., see FIGS. **14** and **16**).

FIGS. **18** to **21** further illustrate a process of installing a cofferdam, according to an embodiment. In FIG. **18**, a cofferdam **1802**, which may be an example of the cofferdam **100** illustrated FIG. **1**, is propelled to a desired location by vessels **1804**. A vessel **1806** with a crane **1810** is also shown. In FIG. **19**, water is being allowed to enter the hollow walls

of the cofferdam **1802**, which has settled to a lower position in the water. Crane **1810** is attached to lift apparatus **1910** in preparation for controlling the position of cofferdam **1802** while cofferdam **1802** is lowered to a subsea surface. In FIG. **20**, cofferdam **1802** is near to the seafloor **2010**, and a lateral position of the cofferdam is being controlled by means of the lift apparatus **1910**. An ROV **2020** is approaching the cofferdam **1802**. In FIG. **21**, the cofferdam **1802** is resting on the seafloor **2010**, and the ROV **2020** is preparing to connect fluid connections to fluidic conduits of the cofferdam.

FIG. **22** illustrates an ROV **2020** making fluidic connections to the fluidic conduits **2210** of the cofferdam, which may be examples of the fluid conduits **408** (see FIG. **4**), according to an embodiment.

FIG. **23** illustrates fluid **2310** being removed from the walls of the cofferdam **1802**, according to an embodiment.

FIGS. **24** and **25** illustrates a filtration tower **2410** of a subsea sediment separation and filtration system (e.g., subsea sediment separation and filtration system **1100**) being lowered into the ocean by a crane **1810** on a topside vessel **1806**, according to an embodiment. Filtration tower **2410** may be an example of filtration tower **1106**, illustrated in FIG. **11**. In FIG. **25**, filtration tower **2410** is resting on the seafloor **2010**, and ROV **2020** is preparing to connect fluid connections to the inlets and outlets of the filtration tower.

FIGS. **26** and **27** illustrate additional components of the subsea sediment separation and filtration system, and the subsea sediment separation and filtration system being assembled, respectively, according to an embodiment. In FIG. **26**, pressure vessels **2610** and **2612**, which may be examples of pressure vessel **1108** (see FIG. **11**), are positioned on the sea floor **2010** near filtration tower **2410**, and ROV **2020** is preparing to connect fluid connections from the filtration tower **2410** to the pressure vessels **2610** and **2612**. In FIG. **27**, a conduit **2702** (which may be an example of conduit **1112**, see FIG. **11B**) enables a water/oil/sediment mixture to be pumped from an interior of the cofferdam **1802** to the filtration tower **2410**. Conduit **2704** (which may be an example of conduit **1114**, see FIG. **11B**) enables sediment to be pumped to a spreader apparatus **2710**, which may be an example of spreader apparatus **1500** (see FIG. **15**). Conduit **2706**, which may be an example of conduit **1116** (see FIG. **11B**), enables an oil and water mixture to be pumped from the filtration tower **2410** to the pressure vessels **2610** and **2612**. Conduits **2708**, which may be examples of conduit **1118** (see FIG. **11B**), enable an oil mixture to be pumped from each of the pressure vessels **2610** and **2612** to skid bladders **2710** and **2712**.

FIG. **28** illustrates a suction device **2810** configured to remove water and sediment and to provide the removed water and sediment to the filtration tower **2410** of the separation and filtration system, according to an embodiment.

FIG. **29** provides a further view of the subsea sediment separation and filtration system in an operational state, according to an embodiment. As described herein, sediment and polluted water are pumped from the interior of the cofferdam **1802** to the filtration tower **2410**. Sediment is pumped to a spreader apparatus (see FIG. **27**) via a conduit **2704**. An oil and water mixture is pumped to pressure vessels **2610** and **2612** via the conduit **2706**. The oil and water mixture are separated by the pressure vessels **2610** and **2612**, and clean water is returned to the ocean. Oil is pumped from the pressure vessels **2610** and **2612** via conduits **2708** to skid bladders **2710** and **2712**.

FIG. **30** illustrates a sediment sprayer **2714** in an operational state, according to an embodiment.

FIGS. **31** and **32** show close up views of the pressure vessels **2610** and **2612** and bladder skids **2710** and **2712**, respectively, according to embodiments.

FIG. **33** illustrates a further view of the complete subsea sediment separation and filtration system in an operational state, according to an embodiment.

FIGS. **34** and **35** show a bladder skid being lifted by a crane to a topside vessel for removal of oil, according to an embodiment. In FIG. **34**, ROV **2020** is attaching a lifting apparatus **3410** to bladder skid **2710** and detaching conduit **2708a** from bladder skid **2710**, in preparation for bladder skid being lifted by the topside vessel (not shown). In FIG. **35**, bladder skid **2710** is being lifted.

FIG. **36** illustrates a ROV **2020** controlling a saw **3610** to cut a damaged pipe **3620** that has been exposed by operation of the suction device, according to an embodiment.

FIG. **37** illustrates multiple damaged pipes **3702** that have been cut in preparation for further repair, according to an embodiment. In one example, the level can be --100' below M/L.

FIG. **38** illustrates a smaller cofferdam **3802** being installed within the larger cofferdam **1802** and around the damaged pipes **3702**, according to an embodiment.

FIG. **39** illustrates an ROV **2020** installing fluidic connections so that fluid may be removed from the smaller cofferdam **3802**, as illustrated in FIG. **40**. In FIG. **40**, water **4002** is being pumped out of the smaller cofferdam **3802** to cause the smaller cofferdam **3802** to descend into the seabed and enable sediment to be removed from around the damaged pipes **3702**, according to an embodiment.

FIG. **41** illustrates the suction device **2810** removing sediment from around the damaged pipes **3702** that are encompassed by the smaller cofferdam **3802**, according to an embodiment.

FIG. **42** shows damaged pipes **4202** that have been further cut in preparation for repair, according to an embodiment. In one example, the level can be --165' below M/L.

FIG. **43** shows damaged pipes **4202** that have been capped, according to an embodiment. In one example, the level can be --165' below M/L.

FIG. **44** shows an ROV **2020** positioning a device **4402** configured to permanently seal the damaged pipes **4202**, according to an embodiment.

In some embodiments, each region may have a lip configured to cover a space between the suction pile and an adjacent region (e.g., covering a space between region **206a** and region **206b** as shown in FIG. **4**). The exteriors of the regions may form a lapped surface that includes an exterior surface or an interior surface of one of the walls (see FIG. **1**). Additionally, the regions can be connected by welding, bolting together, etc.

Conditional language, such as, "can," "could," "might," or "may," unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain implementations could include, while other implementations do not include, certain features, elements, and/or operations. Thus, such conditional language generally is not intended to imply that features, elements, and/or operations are in any way required for one or more implementations or that one or more implementations necessarily include logic for deciding, with or without user input or prompting, whether these features, elements, and/or operations are included or are to be performed in any particular implementation.

The specification and annexed drawings disclose examples of cofferdams having suction piles. The examples illustrate various features of the disclosure, but those of

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ordinary skill in the art may recognize that many further combinations and permutations of the disclosed features are possible. Accordingly, various modifications may be made to the disclosure without departing from the scope or spirit thereof. Further, other embodiments of the disclosure may be apparent from consideration of the specification and annexed drawings, and practice of disclosed embodiments as presented herein. Examples put forward in the specification and annexed drawings should be considered, in all respects, as illustrative and not limiting. Although specific terms are employed herein, they are used in a generic and descriptive sense only, and not used for purposes of limitation.

What is claimed is:

1. A subsea sediment separation and filtration system, comprising:

a first separation device having an inlet and first and second outlets, wherein the first separation device is configured to receive a water/oil/mixture into the inlet, to separate the mixture into a first component containing cleaned sediment and a second component containing an oil/water mixture, and to provide the first component through the first outlet and to provide the second component through the second outlet;

a sediment spreader apparatus having an inlet and an outlet, wherein the first outlet of the first separation device is fluidically connected to the inlet of the sediment spreader apparatus, and wherein the sediment spreader apparatus is configured to receive the first component from the first separation device and to disperse the cleaned sediment of the first component into a subsea environment via the outlet of the sediment spreader apparatus;

a second separation device having an inlet and first and second outlets, wherein the second outlet of the first separation device is fluidically connected to the inlet of the second separation device, wherein the second separation device is configured to receive the second component from the first separation device, to separate the second component into a cleaned water component and an oil component, to provide the cleaned water component through the first outlet of the second separation device into the subsea environment, and to provide the oil component through the second outlet; and

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a storage device having an inlet, wherein the second outlet of the second separation device is fluidically connected to the inlet of the storage device, and wherein the storage device is configured to receive the oil component from the second separation device and to store the received oil.

2. The system of claim 1, wherein the first separation device comprises hydrocyclone devices configured to separate the water/oil/mixture into the first component containing the cleaned sediment and the second component containing the oil/water mixture.

3. The system of claim 2, wherein the first separation device further comprises a plurality of hydrocyclone devices fluidically connected in parallel.

4. The system of claim 1, wherein the second separation device comprises a pressure vessel including a hydrocyclone device configured to separate the oil/water mixture of the second component into the cleaned water component and the oil component.

5. The system of claim 1, wherein the storage device includes one or more bladder skids configured to store the oil component received from the second separation device.

6. The system of claim 1, wherein the storage device is configured to allow oil to be removed from the storage device via an ROV or through fluidic connections to a topside vessel.

7. The system of claim 1, further comprising pumps configured to provide the water/oil/mixture to the first separation device, to provide the first component to the spreader apparatus, to provide the second component to the second separation device, to provide the cleaned water component to the subsea environment of the second separation device, and to provide the oil component to the storage device.

8. The system of claim 1, wherein the system is configured to perform a dredging operation to remove contaminated sediment, to clean and separate the contaminated sediment into the cleaned seawater component, the clean sediment component, and the oil component, to disperse the cleaned seawater and cleaned sediment components into the subsea environment, and to store the oil component.

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